OFFICIAL PUBLICATION

ASHRAE JOURNAL

Heating • Refrigerating • Air Conditioning • Ventilating

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

Gaily, Cecil Boling accepts his Certificate of Appreciation as outgoing President of ASHRAE from incoming President Arthur Hess as Mrs. Boling enjoys the occasion, too

AUGUST 1959

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SACRED COWS OF SCIENCE

Returning from the ASHRAE annual meeting at Lake Placid, with its heavy schedule of technical and committee meetings, conferences, forums and related papers and discussions, offers thought-provoking retrospects. Such meetings are only parts of a broad pattern of similar efforts to improve and strengthen fundamental and practical knowledge in many branches of our highly technical civilization. But contemplate the aggregate outpourings of words and ideas. Someone was quoted the other day as having estimated that the sums of man's stores of information double every 15 years. An appalling thought.

How will even the most dedicated specialists keep pace with such a flood? Eventually, will not anyone who knows anything at all about a subject literally be pushed into the corner of inescapable over-specialization and consequent ignorance—if not unawareness—of the rest of the world and of other aspects of his chosen profession? So much to know, so little time to absorb it and a scant measure of eternity in which to hope to apply it. Today, a man with a newly won Ph.D. has hardly 10 years before he age-wise becomes a doubtful employable for many employers. Shall we not become all but hopelessly bogged down in inundating oceans of facts just as motor traffic is doomed apparently to strangle in increasing millions of automobiles and the impossibility of building city streets and highways fast enough to accommodate them?

Our alarms are more apparent than real.

For, as a conscientious editor, we recognize the problem—so far as published material is concerned—to be an opportunity and challenge in selectivity and effectiveness. The flood of facts must be dammed for storage somewhere for the record, lest it be subjected to the necessity of redeterminations upon later occasions. Our great public libraries are so badly pushed by it all that many volumes perhaps deserving more active availability are achieving warehouse status at the same time that special libraries to serve only specific divisions of informational references are being created.

What we really question is the worthwhileness of at least some of the research projects and expenditures that lead to this flood of facts. Learning need not be an end unto itself. The goal should be usable facts and let posterity take care of its own needs. That does not mean we feel that anyone is wise enough to determine absolutely what is or is not a useful fact. Perhaps our closeness to engineering makes us find that field less vulnerable to such criticism than some others but we would pretend to no hesitancy in a race to cite numerous delvings into obscurity that have led to no more than volumes of erudite nonsense.

Edward R Searles
Editor

Late news highlights

Air Force confers At a 4-day Refrigeration and Air Conditioning Conference, July 13-16, at Wright-Patterson Air Force Base, Dayton, Ohio, the U. S. Air Force provided an intensive indoctrination program. Speakers included President A. J. Hess of ASHRAE, President Paul M. Augenstein of the Airtemp Div, Chrysler Corporation, Chief Engineer F. J. Reed of the Air Conditioning and Refrigeration Institute and various industry authorities upon specialized phases of such activities. Specific topics included standards, heat pumps, absorption systems, centrifugal refrigeration, servicing programs and techniques, preventive maintenance, components, controls and several forums. Project officer for the Conference was William T. Smith, Chief of the Refrigeration and Air Conditioning Section of the U. S. Air Force.

Engineer's work clarified "Scientists make it known, but engineers make it work" is the theme of a series of public service advertisements by Engineers Joint Council designed to create desirable understanding of engineers and engineering by printed media, radio and television, public officials, organizations and advertising agencies. It is hoped the ads will help news writers and editors to present a better picture of the engineer and what he does, and also to clear up existing confusion between the terms "scientists" and "engineers."

Air conditioners rated "Directory of Certified Unitary Air Conditioners," July edition, provides ARI rating data on 1,611 models, representing products of 41 of the 47 manufacturers participating in the Unitary Air Conditioner Certification Program. The next edition will be published October 1. Copies are available from the Air Conditioning and Refrigeration Institute, 1346 Connecticut Avenue, N.W., Washington 6, D. C.

Planning ahead Over 83% of the estimated 39,000 June engineering graduates had completed plans for post-graduation activities a month before graduation, a survey by the Engineering Manpower Commission disclosed. Specifically, the plans were: 63.3%, immediate employment; 10.9%, post graduate studies; 8.4%, military service. An additional 11.7% were considering job offers or had other definite plans; by the third week in May only 5.7% had no immediate plans for the future following graduation.

Weather data The Electric Space Heating and Air Conditioning Committee of Edison Electric Institute has issued a report, "Weather Data for Humidity Control Air Conditioning," which compiles weather data for various areas of the nation. Figures are included for both heating and cooling seasons, showing average mean temperatures, dewpoint, humidity, etc. Copies of the 32-page report are available from Edison Electric Institute, 750 Third Avenue, New York 17, N. Y., at $1.50 for EEI non-members.

Personnel program At the request of the Bureau of the Budget, the National Science Foundation will establish and maintain a program of national information on scientific and technical personnel on behalf of interested Federal agencies. Among the projects this program will undertake are: identification of scientific and technical occupations; pool of scientific and technical personnel; and a periodic study of the demand outlook for various categories of scientific and technical personnel in each major activity.

NSPE grows A total of 4,395 new members joined the National Society of Professional Engineers from February 1 to June 1; this is cited as the largest increase in membership in the Society's history.

Air conditioned homes More than 5½ million American homes now have some form of summer air conditioning – an increase of three quarters of a million in the past year – a Carrier Corp. survey reveals. Texas, New York and Washington, D. C., lead the country with one out of every four completely or partially air conditioned homes located within these states and the capitol city.

Aluminum coils Aluminum alloys and design techniques are now available to meet virtually every operating condition, according to Aluminum Company of America, and three major manufacturers are currently field testing units equipped with all-aluminum coils. Alcoa disclosed that controlled service tests of various aluminum designs in evaporator and wet condenser coils, made in extremely corrosive environments, have shown that properly designed coils will perform well. A further development announced by Alcoa is a zinc soldering process for joining aluminum to itself or to other metals.

BRI conference First of the new multi-subject conferences sponsored by the Building Research Institute of the National Academy of Sciences-National Research Council will be held in Washington, D. C., November 16-19. Sessions on sandwich panel design and architectural metal curtain walls are among those scheduled.

Research reference "A Summary of Engineering Research, 1957-1958," published by the University of Illinois Engineering Experiment Station, Urbana, Ill., contains information on engineering research at the University, the people engaged in individual projects and publications which have grown out of this research during the period from July 1, 1957, to July 1, 1958.

Preservation by radiation Information accumulated by the Army Quartermaster Corps during its first four years of research into the use of ionizing radiation for preservation of food is available in the book, **Radiation Preservation of Food.** Although many of the data have appeared in technical journals, some of the most important findings were drawn from unpublished Government reports, files and technical papers. The 475-page volume includes chapters on the physical, chemical, biological and technological aspects of the process. (Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., price $5.)

New apartments air conditioned 96% of new apartments in Manhattan are air conditioned, a study conducted by Hudik-Ross, Inc., reveals. Of the 58 buildings completed this year or now under way, 51 are equipped with through-the-wall units, 5 have central systems and only 2 do not contain cooling equipment although they do provide special air conditioning outlets.

For one-year warranty Approximately 70% of members of the National Commercial Refrigerator Sales Association are dissatisfied with the five-year warranty and advocate a return to the one-year warranty period, a survey undertaken by the NCRSA Board of Directors reveals. Excessive details and losses incurred by members are primary complaints cited.

Processing methods Potato Processing by William F. Talburt and Ora Smith in collaboration with a group of specialists covers various phases of potato processing, including detailed descriptions of processing procedures for most types of frozen, dehydrated and canned products; a complete discussion of raw material storage problems; methods for selection of potatoes for processing; a thorough treatment of storage diseases; and an evaluation of major potato varieties. (AVI Publishing Company, Inc., Westport, Conn., 475 pages.)

Whirlpool chair First professional chair to be endowed at the School of Business Administration of the American University, Washington, D. C., the Whirlpool Chair of Marketing has been established through a grant from Whirlpool Corporation. Purpose of the chair is to conduct research into problems and trends in marketing and to make special studies of the home appliance industry.

Thermoelectricity on ships Design studies to test the feasibility of thermoelectric heating and cooling in shipboard air conditioning will be undertaken by Carrier Corporation under a contract from the U.S. Navy. Successful completion of the 18-month program, which will contemplate preliminary design and analysis, could lead to a large-scale development of thermoelectric heat pumps, according to Dr. J. F. Downie Smith, research and development vice president of Carrier.

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AUGUST 1959

Suppression of oscillations

in gas-fired residential heating equipment

C. F. SPEICH

A. A. PUTNAM

Oscillations, as differentiated from vibrations and other noise sources*, have preoccupied manufacturers, installers, and users of residential heating equipment for many years. Through experience gained by trial and error, a number of different suppression techniques have been found which are effective in some, but not all, circumstances. Lack of understanding of the causes of oscillations forestalled understanding the reasons for the uncertainty of success of the suppression techniques. The entire oscillation problem has been further aggravated in recent years by the use of smaller, more compact heating units placed nearer to the living quarters of residences. Also, people in general have become more noise conscious.

In the light of these developments, a research program jointly sponsored by the American Society of Heating and Air-Conditioning Engineers, Inc., the American Gas Association, and the Oil-Heat Institute of America, Inc., was initiated at Battelle Memorial Institute in 1954, to study the fundamental causes and methods of suppressing oscillations and pulsations in both gas- and oil-fired residential heating equipment.

The original of this paper is the fifth in a series of reports[1,2,3,4] on the results of the research program. Techniques for the suppression of oscillations in gas-fired heating equipment utilizing burners of both single- and multiple-port type are first outlined in simplified form for ready reference. Since the mechanisms of oscillation for each type of burner unit differ, the remainder of the paper has been divided into two sections, one devoted to each type of burner. Each section includes a brief summary of the mechanism of oscillation, and outlines in limited detail the techniques that can be used to suppress oscillations.

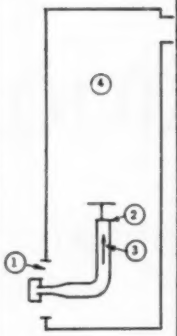
SUPPRESSION PROCEDURES

The sciences of combustion physics and heat transfer are closely connected with the design of gas-fired heating equipment. When oscillations occur in these units, it must be realized that a third science, namely acoustics, also enters into the problem. In the past, when objectionable oscillations occurred, frequent resort was made to change some of the variables affecting the combustion process in an attempt to suppress the oscillations. Unknowingly, these changes also affected the acoustic behavior of the heating unit. However, since these acoustic characteristics were unknown, the trial-and-error methods of suppressing oscillations were not always effective on a consistent basis.

This paper concentrates on the acoustic aspects of the combustion oscillation problem. Therefore, it is felt that designers, installers, and service representatives should all find information which will be helpful in accomplishing the suppression or elimination of oscillations in gas-fired heating equipment. It is realized that not all of the methods suggested will be practical from the standpoint of the combustion and heat transfer specifications which must be met for a

* Other noise sources might include random flame noise, panel vibrations, vibrations of internal elements due to vortex shedding from sharp edges, start-up and shut-down noise, ignition spark amplifications, and the like. This paper deals only with combustion-driven oscillations.

C. F. Speich is Principal Mechanical Engineer, A. A. Putnam is Division Consultant, both at the Battelle Memorial Institute. This paper, an abridgement of the original version which was prepared for inclusion in the Transactions of ASHRAE, was presented by title at the ASHRAE annual meeting, Lake Placid, N. Y., June 22-24, 1959.



Furnace Characteristic or Adjustment	Effect of Change in Furnace Characteristic or Adjustment on Amplitude of Oscillation — Observed Frequency: Less Than Resonant	Greater Than Resonant	Time When Suggested Procedure is Applicable	Remarks and Applicable References
Single-Port Burner Units				
Secondary-air opening (1)	Increasing either item lowers amplitudes of oscillation	Decreasing either item lowers amplitudes of oscillation	Design, installation, service	Effect on resonant frequency slight; increases acoustic radiation to outside; effect on over-all noise output unknown because of nonlinear effects of oscillation (see Appendix C, Ref 4)
Burner-port diam (2)			Design, possible future application in installation & service	Prevention of flashback and blowoff require changes in flow rate and mixture ratio
Primary-air flow rate (3)	Decreasing either item lowers amplitudes of oscillation	Increasing either item lowers amplitudes of oscillation	Design, installation, service	Decreasing flow rate may cause CO, CO_2, and stability problems; increasing flow rate will cause increases in random combustion noise and instability of flame
Volume of combustion chamber (4)			Design	Only practical for proposed designs
Firing rate	These items have little or no effect on amplitude of oscillation			Except at high primary-air flow rates
Distribution of secondary air				
Secondary-air flow rate				
Length of burner tube				Increase in length produces slightly lower amplitudes of oscillation
Temperature of combustion gases				Indeterminate effect on the amplitude of oscillation
Burner position				Indeterminate effect on the amplitude of oscillation
Spreader height				
Spreader diameter				

Table Ia Factors affecting oscillation amplitude for single-port burner units

specific unit; compromises must be made. Identification of methods of oscillation suppression best suited for specific units are avoided here in preference to outlining the general methods useful in designing or modifying a large number of different units.

To make maximum use of the suppression techniques outlined herein, it is necessary to know how near the normal furnace operating conditions are to those operating conditions for which the maximum amplitudes of oscillation occur. For single-port units, it will generally be sufficient to know whether the existing oscillating frequency is less than or greater than the resonant frequency of the furnace.

For multiple-port units, one may picture a relief map of intermixed flat-topped hills and valleys where the hills represent oscillating regions and the valleys, non-oscillating regions. The normal operating conditions of a specific unit will place it somewhere on the hypothetical map. If at these operating conditions the unit is found to be on one of the hills and thus found to oscillate, then it is obvious that ways must be found to get down into a valley. It is apparent, however, that the relative locations of these hills and valleys dictate the appropriate means of reaching a valley. As is shown in the original version of this paper, the most practical means of finding the location of these hills and valleys is to conduct experimental tests on a particular arrangement of burner face at the port level and to determine how extensive a change in one or several variables is required to stay out of oscillation.

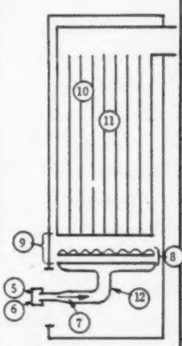
Tables Ia and Ib present for both single- and multiple-port burner units a summary of all of those variables which have been found (1) to affect the oscillation amplitude or (2) to have little or no effect on the amplitude. For these tables, it is assumed that when one variable is changed, all others are held constant. As can be seen in the table for single-port burner units, the effect of changing the variables will depend on whether the observed frequency of oscillation is less than or greater than the resonant frequency of the heating unit. It should be possible to ascertain the relative value of the observed frequency with respect to the resonant frequency by noticing what effect each variable would have on the amplitude of oscillation.

For the multiple-port burner units, it should be emphasized that the effects from changes in the several variables hold on the average for a large number of units. Any specific unit may react in just the opposite manner. Thus, the need for knowing where the operating conditions are with respect to those of the oscillating regions is made doubly important.

For a more complete understanding of the suppression techniques described in the table, a list of applicable references is given in the right-hand column. These references are the significant publications resulting from this over-all research program. The remaining sections of this paper review briefly the essential features of the research results that have been presented in considerable detail in the referenced publications.

SINGLE-PORT UNITS

Results of the preliminary investigations and a detailed discussion of the proposed mechanism of oscillation of single-port burners have been presented in two of the previous papers of this series[1,4]. In essence, the mechanism which has been proposed states that there are two phenomena involved in the generation of the oscillations. These are (1) an aerodynamic vortex-shedding from the lip of the burner port and (2) a periodic pressure oscillation in the combustion chamber, with a frequency close to the resonant frequency of the chamber.



Furnace Characteristic or Adjustment	Effect of Change in Furnace Characteristic or Adjustment on Amplitude of Oscillation — Observed Frequency	Time When Suggested Procedure is Applicable	Remarks and Applicable References
Multiple-Port Burner Unit			
Firing rate (5)	Increases in these variables will increase chances of oscillation	Design, installation, service	The chances of increasing or decreasing oscillations is based on the average of a large number of units. For a particular unit, the relation of the normal operating conditions to those conditions where oscillations occur may cause the effects of various furnace characteristics to contradict this table. For additional material, see Reference 3.
Primary-air flow rate (6)		Design, installation, service	
Primary-mixture ratio (7)		Design, installation, service	
Altitude (firing-rate constant)		Installation	
Ratio of flame length to dark space (8)	Increases in these variables will decrease chances of oscillation	Design, installation, service	
Distance from burner port level to heat exchanger (9)		Design; only small changes possible during installation & service	
Damping losses (10)		Design	
Frequency of heating unit (11)		Design	
Frequency of burner (12)	Effects of oscillations average out	Design	

Table Ib Factors affecting oscillation amplitude for multiple-port burner units

The vortex-shedding produces a periodic variation in the rate of heat release of the flame.

It is the coupling between the rate of heat release and the pressure oscillation which determines the amplitude, and to a small extent, the frequency of the oscillation. The difference between the vortex-shedding frequency and the frequency of the pressure oscillation determines the extent of this coupling. If this frequency difference is small, the oscillation will lock in together, only one frequency of oscillation will occur, and the amplitude of oscillation will be high. If, on the other hand, this difference in frequency is large, the amplitude will be small especially if the frequency of vortex-shedding is the lesser of the two frequencies.

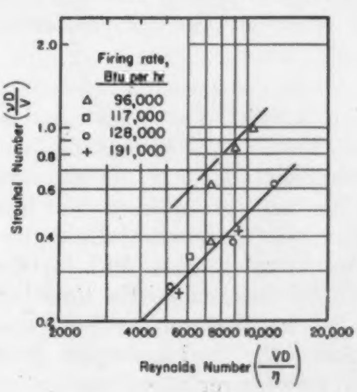
Fig. 1 shows the correlation obtained using data from one burner of constant port diameter external to the furnace. In this correlation, the Strouhal number is plotted against the Reynold's number. Strouhal number, often used in studies of vortex-shedding phenomena, is defined as the product of the vortex-shedding frequency and the burner-port diameter divided by the average velocity of the combustible gases through the burner port. The Reynold's number, defined as the ratio of the inertial forces to the viscous forces of the gases, is commonly written as the product of the average velocity of the combustible gases through the burner port and the burner-port diameter divided by the kinematic viscosity of the gases.

The fact that the correlation between the Strouhal and Reynold's numbers was good when the burner was external to the furnace indicates that the vortex-shedding is of an aerodynamic origin rather than a result of some acoustical effect related to the combined burner-furnace space configuration. Thus, the normal frequency of the vortex-shedding is dependent only on the design geometry and flow conditions at the burner lip.

SUPPRESSING OSCILLATIONS

Suppression of the oscillations in single-port burner heating units depends on the ability to decrease the coupling effects between the rate of heat release and the pressure oscillation. Basically, this can be accomplished by increasing the difference in frequency between the two phenomena.

Fig. 1 Firing rates for the single-port burner external to the experimental burner



Changing the average port velocity—Using the data from Fig. 1 and assuming that the kinematic viscosity of the gases and the burner-port diameter are constant, it can be shown that the frequency of vortex-shedding varies directly with the average velocity of the gases passing through the burner port. If, for an example, a heating unit is considered to produce objectionable oscillations when the frequency of vortex-shedding is less than the resonant frequency of the heating unit, then increases in the average port velocity will cause an increase in the amplitude of oscillation.

These increases in oscillation amplitude will continue until the frequency of vortex-shedding exceeds the resonant frequency of the unit. Further increases in the vortex-shedding frequency will cause a general decrease in the amplitude of oscillation. As a general rule, it can be said that oscillation suppression can be achieved by making changes in the average port velocity causing the difference between the vortex-shedding and the resonant frequencies to increase.

Changing the burner-port diameter—Since each of the dimensionless

ratios used in the correlation depicted by Fig. 1 have as one term the burner-port diameter, it would be expected that changes in this diameter would affect the frequency of the vortex-shedding. However, the 1:1 slope of the lower line drawn through the data on Fig. 1 means that when the two terms are equated, the diameter term cancels out.

Since it is volume rate of flow of the combustible gases issuing from the burner which is of major concern to burner design, this volume rate of flow can be substituted for the average burner-port velocity when equating the two dimensionless terms. This substitution reenters the burner-port-diameter term, taken to the fourth power, into the resulting equation. With the equation in this form, and the volume rate of flow kept constant, it is found that the frequency of vortex-shedding will vary inversely as the fourth power of the burner-port diameter.

It should be realized that changes in burner-port diameter will also change the average velocity of the gases leaving the burner port. If the diameter is increased, both the frequency and flow velocity will decrease. However, as a complication, the flash-back and blow-off limits will both be changed by these modifications in burner-port diameter and flow velocity. It may be necessary to change the volume flow rate or the mixture ratio, or both in order to attain satisfactory combustion conditions.

As part of this investigation, several experimental burners were built which had port diameters different from that of the single-port burner generally used in these studies. These studies did show that oscillation suppression could result from diameter changes.

Altering vortex-shedding characteristics – Changes in the burner lip that alter the type of vortices shed were also expected to alter the amplitude of oscillation. For instance, a burner with a spiral lip of the proper advance might cause the vortices to shed continuously. Other configurations might cause the vortices to shed irregularly, thus preventing a periodic heat release. The breaking up of the large vortices into smaller ones is still another possible means of reducing the amplitude of oscillation. Small vortices not only tend to decay faster than larger ones, but tend to cancel each other. This last type of configuration was found to be quite effective in reducing the amplitude of oscillation.

Effect of furnace volume changes – As indicated previously, the amplitude of the pressure oscillation is related to the closeness of the natural vortex-shedding frequency to the resonant frequency of the heating unit. Thus, reductions in amplitude should be possible not only by changing the frequency of the vortex-shedding away from the furnace frequency, but also by changing the resonant frequency of the heating unit away from the vortex-shedding frequency. Since the resonant frequency of the heating unit is a function of its volume and internal configuration, decreasing the volume will increase the resonant frequency of the unit. Thus, changes in unit volume can be used as a means of increasing the difference in the two frequencies.

MULTIPLE-PORT UNITS

Multiple-port, ribbon, or slot burners differ from single-port burners in the manner in which the oscillations are driven. The difference is that vortex-shedding is not involved. Rather, the periodic heat-release rate necessary for driving results from a pulsation of the supply of the mixture of fuel gas and primary air to the flame. This means by which combustion oscillations may occur has been long recognized, but only recently, in two previous papers of this series,[1,3] has it been associated with the multiple-port type of burner used in residential heating units.

There are three furnace-burner variables which determine the presence of oscillations in multiple-port burner heating units. These are (1) the natural frequency of the burner, (2) the natural frequency of the heating unit, and (3) the length of time, called the time lag, needed for the combustible gases to pass from the burner-port level to an average region of combustion

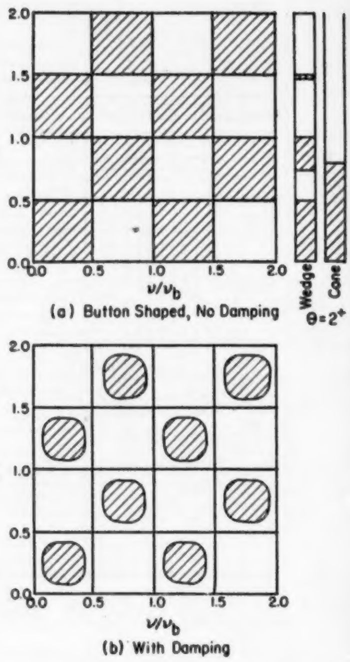


Fig. 2 Regions of pulsation in simple multi-port burner

in the flame. Using a mathematical treatment, such as shown in Reference 3, it is possible to relate these variables to predict regions of oscillation alternating with regions of non-oscillation. On the basis of the most simplified mathematical analysis, there are an infinite number of these regions, but in practice the number is limited to only a few.

Fig. 2a indicates this type of array for the simple theory. The symbols used are defined as follows:

- ν natural frequency of heating unit
- τ time lag
- ν_b natural frequency of burner
- θ measure of the ratio of flame height to the distance of the flame base above the burner-port level

The button-shaped flame is a theoretical concept which depicts the flame as being infinitesimally thin and flat. Deviations from this flame shape to one of the form of a wedge or cone will alter the regions in which oscillations can occur. An example is shown by the bar graphs to the right of the figure.

When acoustic damping occurs, the regions of oscillation are also decreased as shown in Fig. 2b. Damping occurs from friction in the system or acoustic radiation

from the system and represents a means of taking energy out of the oscillating system.

Fig. 2 is not the most advantageous array to use to determine the oscillating regions of a specific unit. This arises because of the difficulty of calculating accurate values of time lag. As defined in Reference 3, the time lag is a function of, among other things, the flame speed and dark space for the fuel-air mixtures used in the combustion process. There are not enough published data on these items available to permit computation of accurate values of the time lag. Therefore, a procedure has been devised by which the problem of the calculation of time lag has been circumvented. The aim of this procedure is to produce a set of curves of the changeover lines corresponding to the horizontal lines of Fig. 2, but in terms of firing rate, mixture ratio, and observed frequency of oscillation. The ratio of observed frequency to burner frequency would determine which of the alternating regions would be prone to cause oscillation.

In this procedure, it is suggested that a series of investigations be made using one design of burner-port level and a number of different sized burner bodies and different lengths of heat-exchanger sections in order to obtain a range of burner and heat exchanger natural frequencies. It should be emphasized that the frequency is the important factor and exchangers built up of available components or flat plates are sufficient.

Two techniques are outlined in the original version of this paper by which the data may be analyzed. In the first, the mixture ratio is held constant and the firing rate varied. As the firing rate is increased in small steps, the ranges of oscillation and corresponding frequencies are recorded. The reciprocal of the frequency is plotted against the reciprocal of the primary gas-flow rate, for each set of data.

In the second method of handling the data, attention is focused on one small increment of frequency, given by the fundamental mode of one heat exchanger and possibly higher modes of larger exchangers. Firing rate is held constant for each run, and mixture ratio varied. Whether or not oscillations occur at a series of closely spaced points is determined and indicated on a plot of per cent theoretical primary air as a function of volume flow rate of primary mixture.

These methods will establish the locations of regions of oscillation and non-oscillation in terms of easily measured furnace and burner variables.

Using this basic information, estimates can then be made as to the vulnerability to oscillation of a new heating unit design with this same arrangement of burner face at the port level. In the case of other units where oscillation problems exist, estimates can be made of the necessary changes required to produce a substantially oscillation-free unit.

CONCLUSIONS

With most research programs, the answering of one set of questions often leads to the asking of a host of others. This has been true in this program. It is felt that there are at least two items related to single-port burners brought to light in this program which require further study. One of these is the physical mechanism by which the vortices are shed from the burner port lip. At the same time, the variation of the vortex-shedding frequency with burner-port diameter, configuration, and flow velocity should be studied more extensively than was done during this program. This information would be valuable to the designer of burners, not only in determining more completely what designs would have the least chance of producing objectionable oscillation, but also in leading to a general understanding of rates of heat transfer and mixing associated with such burners even when combustion-driven oscillations are not present.

A second program of interest for single-port burner heating units would be to study in more detail the coupling effect between the periodic variation in heat release and the pressure oscillations. Included in this investigation should be an intensive study of the feedback effect which is hypothesized as being the triggering mechanism needed to sustain the vortex-shedding. It is believed that if this coupling effect were better understood, more suppression techniques might well be brought to light.

It would appear that, from other than an academic standpoint, further basic research on multiple-port units would not be particularly profitable at present. It would be of greater benefit to start compiling information systematically on various arrangements of burner face at the port level and the conditions under which they oscillate, in order to arrive at a practical set of data which would give a designer a feeling for the actual changes that result from various changes in operating parameters. This follows from the fact that so many variables are involved, values of which are not exactly known, and from the fact that the theory is reaching a stage of complication where further elaboration results in a marginal return.

ACKNOWLEDGMENT

This program was monitored by representatives of each of the sponsoring organizations through membership on the Pulsation Research Steering Subcommittee of the ASHAE Technical Advisory Committee on Combustion. The able assistance of the members of that Subcommittee in guiding the work, and in providing necessary information and materials is gratefully acknowledged. Special thanks are due to personnel of the Armstrong Furnace Company and the Surface Combustion Corporation, both of Columbus, Ohio, who provided the experimental furnaces and burners used in this investigation. It is also desired to acknowledge the assistance of W. R. Dennis and Gail M. Clough in obtaining various portions of the data used herein.

REFERENCES

1. Putnam, A. A. and Dennis, W. R., "Pulsations in Residential Heating Equipment—Preliminary Results", ASHAE Research Report No. 1596, ASHAE Transactions, Vol. 63, 1957, p 153.
2. Speich, C. F., Dennis, W. R., and Putnam, A. A., "Acoustic Coupling of Residential Furnaces With Their Surroundings", ASHAE Research Report No. 1612, ASHAE Transactions, Vol. 63, 1957, p 413.
3. Putnam, A. A., "Pulsations in Residential Gas Furnaces With Multiple-Port Burners", Research Report No. 1641, ASHAE Transactions, Vol. 64, 1958, p 377.
4. Speich, C. F. and Putnam, A. A., "Pulsations in Single-Port Gas-Fired Residential Heating Equipment" — ASHAE Journal Section, Heating, Piping, and Air Conditioning, November, 1958, p 139.

Experimental research

on lubrication in Refrigerant-12 systems

NORMAN SHARPE
Member ASHRAE

System design courses encounter difficulties with the flow of refrigerant-oil solution through Refrigerant-12 lines. Diverse recommendations make the problem one of determining which flow conditions should be taught. For example, when studying oil travel accompanying Refrigerant-12 vapor flowing upward in a vertical suction line one recommendation was for a minimum vapor velocity of 600 fpm; while another was for 1500 fpm. Large differences also exist in recommended flow conditions for horizontal lines. As none of these references cited experimental data, research was undertaken by the author, with results reported herein.

Finding a solution to the problem of which flow conditions for Refrigerant-12 lines should be recommended to the student of system design proved to involve not a clarification of existing reference material, as was expected, but entirely new experimental research. Correspondence with the authors of the reference material already published on recommended flow conditions proved little help in the solution of the teaching problem, as in most cases the data were based on "field experience" rather than on research.

Experimentally, it was found that certain of the assumptions based on field experience were not necessarily true. In one case, for example, observations had been made through a transparent section placed in a vertical riser. If the oil[1] ripples along the surface of this transparent section appeared to move upward it was inferred that the oil was traveling upward, while if the ripples were moving downward it was assumed that oil was accumulating at the bottom of the riser. This was shown by experiment to be an inaccurate assumption, and indicated a need for further research.

A preliminary examination was then made of the danger of oil settling in the discharge line or suction line. To do this balanced, sighted gauges (as shown in Fig. 1) were placed in horizontal runs at the bottom of suction and discharge risers. If the vapor velocity could be considered to be the criteria, then the danger of oil settling in the suction line appeared to be greater than the settling of oil in the discharge line. Our studies have therefore been confined to the suction line.

Further investigation using the balanced gauge method of testing showed that the shape of the fitting at the bottom of the riser was one of the most important factors in avoiding oil accumulation. At low vapor velocity there was considerable settling in the horizontal run if a long turn ell were used. This accumulation was greatly reduced by the use of a short turn ell. Finally, there was **no accumulation at all,** when a "P shaped trap," constructed as shown in Fig. 2,[2] was used at the bottom of the riser at any vapor velocity which we were able to test. Our results could not be explained from previously published literature so we decided that a study using transparent fittings and lines was in order. One of these studies has been completed and the other is still in progress.

I In the first study, an oil trap was constructed of extra-strong Pyrex glass with dimensions as shown in Fig. 3. The horizontal and vertical legs were of sufficient length to observe the horizontal and vertical oil flow patterns. This trap was installed in the suction line of a 3 hp Refrigerant-12 system as shown in Fig. 4.

The compressor operated at about 1730 rpm during all tests. Its lubrication was partially forced feed and partially splash. It had small narrow counterbalances on the crankshaft which did not cause excessive splash. It was factory equipped with a suction line strainer with a small internal port and check valve arrangement to allow the oil to return to the crankcase. A napthene base lubricating oil of 300 SSU viscosity was used.

The system used a direct expansion coil as an evaporator. The suction pressure at the coil was approximately 50 psia (38 F) and the superheat leaving the coil was approximately 9 F during all tests. Capacity regulation was achieved by throttling the air quantity through the fin coil evaporator, and the returning suction vapor with the suction service valve on the compressor. No discharge line oil separator nor liquid to suction line heat exchanger was used.

Two lengths of suction risers

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[1] The refrigerant-oil solution will be referred to as "oil" although it is realized that this solution contains a large percentage of refrigerant.

Norman Sharpe is Head of the Department of Air Conditioning and Refrigeration Engineering at California State Polytechnic College. This paper was presented at the Regional Meeting of ASHRAE in Los Angeles in March.

[2] Hereafter a "P shaped trap" will be referred to simply as an "oil trap."

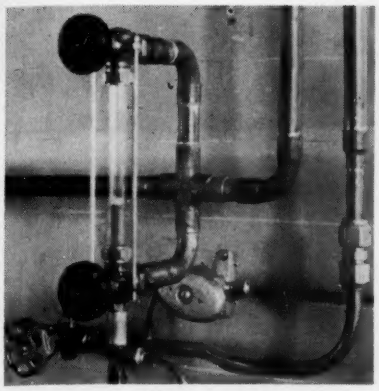


Fig. 1 Balanced sight gauge

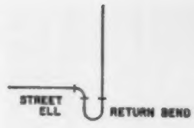


Fig. 2 Construction of a P-shaped ell

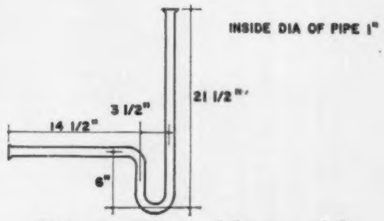


Fig. 3 Trap of heat- and shock-resistant glass was used in these tests

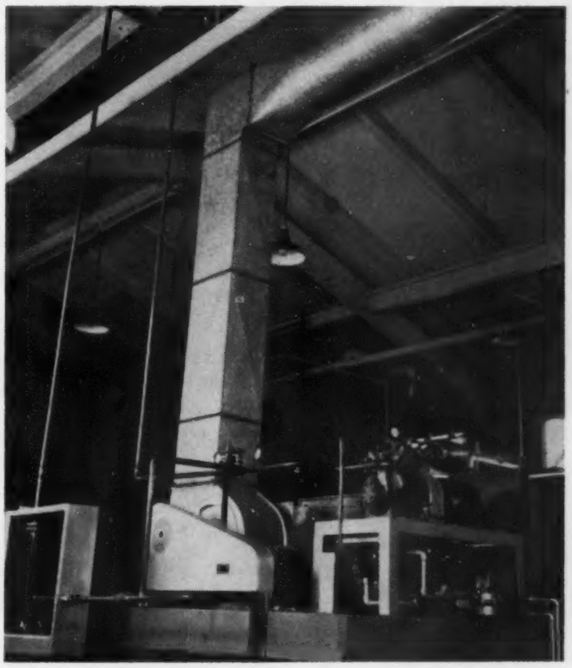


Fig. 4 Test system as set up for study of the performance of the P-trap

were used: 12 ft 6 in. and 3 ft 0 in. Both risers were constructed of 1⅛-in. OD type L copper tubing. The glass oil trap at the bottom of the riser had an inside diameter of 1.0 in. Its other dimensions are shown in Fig. 3.

Four sets of photographic studies of the transparent oil trap were made as follows: (1) with a vapor velocity slightly above 600 fpm using the 12 ft 6 in. riser, (2) with the vapor velocity slightly above 600 fpm using the 3 ft 0 in. riser, (3) with the vapor velocity slightly under 500 fpm using the 12 ft 6 in. riser, and (4) with the vapor velocity slightly under 500 fpm using the 3 ft 0 in. riser. Photographs and measurements were made for each test after the system had been in operation for more than a two hour period in each case. The four tests will be reported separately.

Test No. 1 Fig. 5 is a photograph of the oil moving along all parts of the trap in a satisfactory manner. The riser height was 12 ft 6 in. and the vapor velocity was 625 fpm. The oil flowed along the bottom of the horizontal leg, in various patterns depending upon the position in the U bend, and in a continuous upward creeping movement of a rippling liquid film in the vertical leg. The velocity of the oil movement could not be measured; however, in the horizontal leg the ripples at the top of the oil stream appeared to move at about 6 fpm, while the oil ripples along the surface in the vertical leg appeared to move at less than 1.0 fpm.

It must not be inferred that the velocity of the rippling movement is the same as that of the flow of the oil film. In the riser, no doubt, the ripples are formed by the two following opposing forces: (1) the upward viscous drag of the refrigerant vapor on the oil film and (2) the downward force of gravity on the oil film. It is even quite possible that the ripples may appear to move upward while that portion of the oil film next to the surface of the pipe is moving downward. Let us consider a seashore analogy.

Suppose that you were standing at the end of a pier at the seashore and were looking downward at the waves. You would see these large ripples moving at considerable velocity toward the shore. If you made the assumption that the ocean water was moving toward the shore at the same velocity as the waves, you would immediately become afraid that the adjoining resort city would be flooded. Actually, the tide might be receding and under this condition the resultant movement of the ocean water would be away from the shore.

The only definite criteria of the upward or downward travel of oil is whether there is a continuously increasing collection of oil at the bottom of the trap. If there is no collection of oil at the bottom of the trap or if the amount of oil at this point strikes an equilibrium, then the amount of oil entering the trap would equal the amount of oil leaving the trap and there would be an upward flow of oil in some manner.

The velocity of the ripples, however, may have some significance. Since they are undoubtedly caused by two opposing forces, the average velocity of the oil flow in the film must be considerably slower than that of the ripples and if the oil flow were by film travel only the return of oil to the compressor crankcase would be slow indeed.

No accumulation of oil at the bottom of the U bend appeared while the system was in operation. When the system was stopped the collection of oil at the bottom of

the U trap was almost negligible indicating that the oil film in the vertical riser must have been quite thin. There was no measurable change in the crankcase oil level during the test, hence the oil return was considered satisfactory.

Test No. 2 Fig. 6 reproduces a photograph of the oil flowing through all parts of the trap under similar conditions of operation to that of Test No. 1 in all respects except that the riser was only 3 ft 0 in. rather than 12 ft 6 in. The oil flow pattern was the same as that in Test No. 1 in all respects, indicating that the height of the riser had no effect on the oil flow pattern.

At vapor velocities between 500 and 600 fpm with either length of riser the oil flow pattern in the vertical leg of the trap was unstable. No photographs were taken within this range.

Test No. 3 Fig. 7 indicates oil movement through all parts of the trap, using 12 ft 6 in. riser as in Test No. 1 but with the vapor velocity reduced to 490 fpm. The ripples along the top of the oil stream in the horizontal leg moved at about 3.5 fpm, considerably slower than in Test No. 1. There was an initial accumulation of oil at the bottom of the U bend as shown in the figure, but this quantity quickly struck an equilibrium and remained constant throughout the test. Upon turning off the system and allowing the vertical riser to drain, this accumulation was about 0.5 in. deep. Upon starting the system again the accumulation of oil did not travel up the riser in a slug but spread evenly on the surface of the riser. The uneven ripples in the vertical leg of the trap appeared to move downward at a velocity of less than 1.0 fpm. Since the quantity of oil at the bottom of the U bend remained constant we can say that the downward flow of oil along the vertical leg must have been equal to the upward flow with the vapor. There are therefore two modes of oil travel up a riser: along the surface of the tube and also with the refrigerant vapor.

There was no measurable change in the crankcase oil level during the test. We must therefore conclude that the travel of oil through the suction line was satisfactory; however, with a long branched suction line oil return difficulty might be encountered under nonstabilized conditions of operation because of the thicker oil film in the vertical line and the slower oil movement in the horizontal lines.

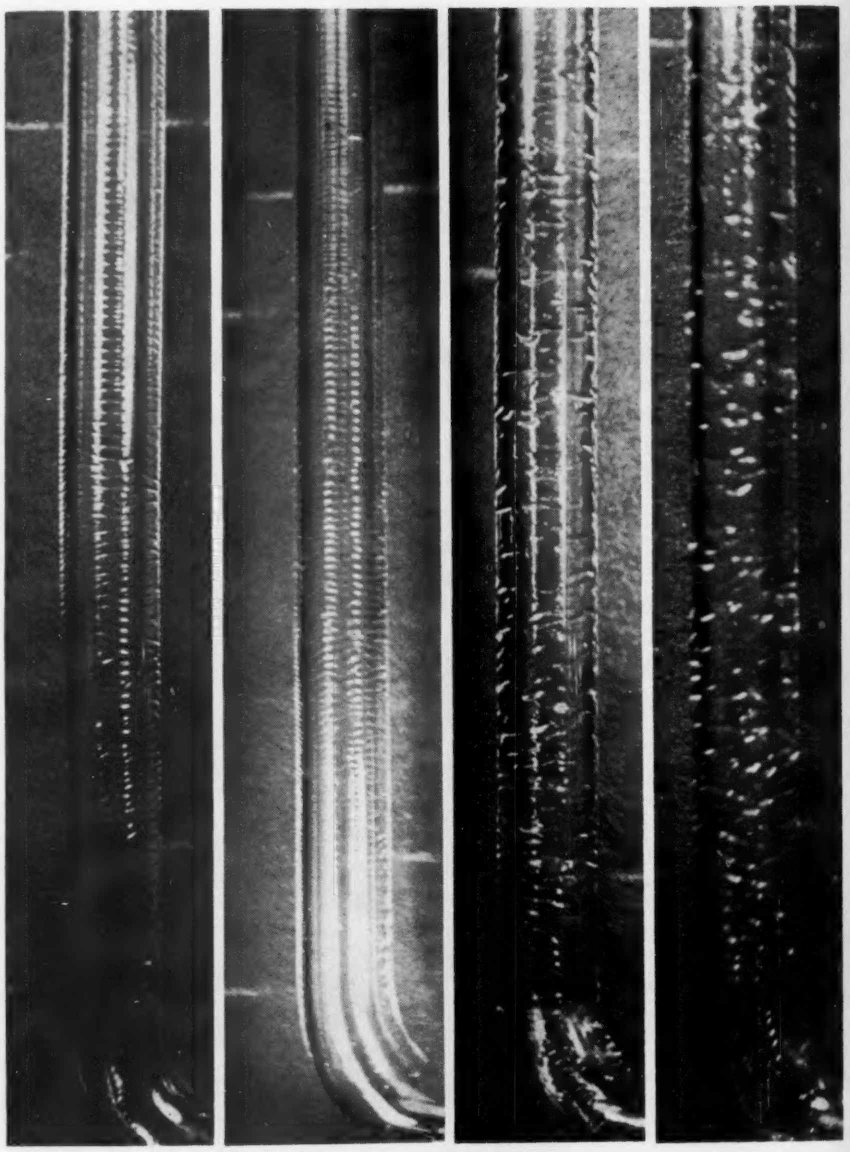


FIG. 5 FIG. 6 FIG. 7 FIG. 8

Flow patterns of liquid films. Fig. 5 Moving up inside glass section with 12 ft 6 in. riser; Fig. 6 With 3 ft 0 in. riser; Fig. 7 Moving down with 12 ft 6 in. riser; Fig. 8 With 3 ft 0 in. riser

Test No. 4 Fig. 8 shows oil movement when the system was operating under similar conditions to that of Test No. 3 in all respects except that the 3 ft 0 in. riser was used rather than the 12 ft 6 in. riser. The oil flow pattern was similar to that of Test No. 3 in all respects again indicating that the height of the riser had no effect on the oil flow pattern. No tests were made on the percentage of oil in circulation with the refrigerant at the time the photographs were taken, but subsequent measurements indicated that the oil concentration was nearly 1.0 percent by weight of the refrigerant during all the tests of this study.

SUMMARY

1. Height of the riser had no effect on the oil flow pattern in the trap or in the riser.

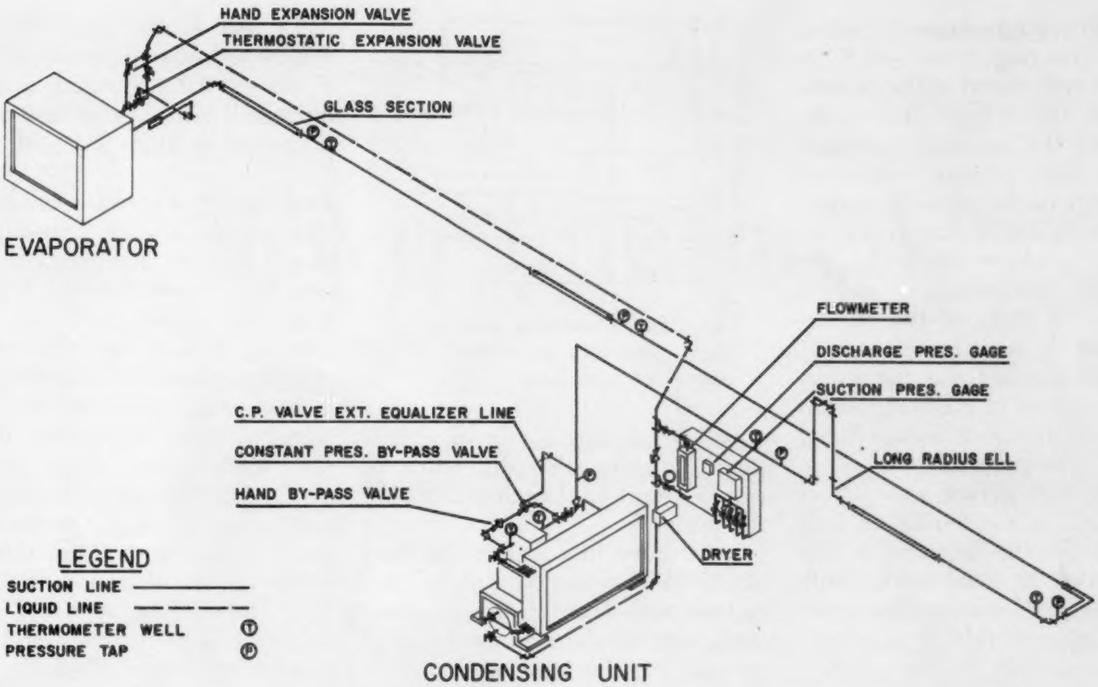


Fig. 9 Schematic arrangement of test system

2. There were two modes of oil travel upward in suction risers: (1) as a rippling oil film along the inner surface of the tube and (2) as oil vapor or mist traveling along with the refrigerant vapor.

3. The oil traveled along the horizontal run in a rippling stream at a low velocity when compared to that of the refrigerant vapor flow.

4. The "P" shaped oil trap afforded proper drainage of the horizontal run and satisfactory flow of the oil upward in the riser at a lower velocity than was heretofore deemed advisable. At vapor velocities above 600 fpm no oil accumulation appeared at the bottom of the trap, and the ripples of the oil along the tube surface moved smoothly upward at a low velocity. At vapor velocities between 500 and 600 fpm there was a transition range under which condition it was difficult to determine the direction and velocity of the ripples.

At vapor velocities below 500 fpm the ripples of the oil along the tube surface moved slowly downward. At vapor velocities below 500 fpm a small pool of oil appeared at the bottom of the U bend of the trap; however, the size of this pool remained constant after an equilibrium had been established in the system.

5. Satisfactory oil return was achieved in all tests on this system; however, if the suction line had been long and branched, with the system operating under nonstabilized conditions, and with vapor velocities below 500 fpm, oil return difficulty might be encountered because of the thicker oil film in the vertical line and larger oil stream in the horizontal line and the slow rate of flow in either case.

II For many years we have received reports on difficulty of oil-return where long horizontal suction lines were involved. Most of these reports were concerned with refrigerating systems for super markets. Also, the first study indicated that, because of low velocity of oil travel in either horizontal or vertical lines, considerable time could elapse on long lines between the time oil left the compressor crankcase and was returned to it. Because of these circumstances we have set up a test system as indicated in Fig. 9 with a 115 ft long suction line constructed of one in. nominal diam schedule 40 steel pipe with 1.0-in. inside diam extra strong heat-resistant glass sections as indicated.

A riser 3 ft 0-in. high preceded by a long turn ell constructed by bending a piece of schedule 40 steel pipe on a 3.5-in. radius was included in the suction line as indicated. The purpose of this riser was to give as poor a flow condition for the oil as possible.[3]

A 2 hp, 2 cyl Refrigerant-12 compressor running at 575 rpm was used. It had trunk type pistons with one compression ring above the entry of the suction vapor and two scraper rings below the entry of the vapor. It had splash lubrication. The crankshaft was not counter-balanced. One peculiarity of this compressor was that it had no internal nor external connection between the suction vapor and the compressor crankcase. The compressor was in good condition although it was 14 years old. It has never had any parts replaced. In spite of its age it pumped but little oil. In order to vary the oil quantity in circulation an external connection was made from the bottom of the compressor crankcase through a needle valve to the suction line. A naphthene base lubricating oil of 300 SSU viscosity was used.

The capacity of the system was regulated by regulating the air quantity flowing through the blower coil and throttling the suction vapor at the compressor.

A preliminary study showed

[3] It was found in a previous study that there was more danger of oil settling before a long turn ell than a short turn ell. It was also found in the previous study that there was no difference in oil film pattern in a 3 ft 0 in. riser and a 12 ft 6 in. riser.

no difficulty of oil return at suction pressures ranging from −20 F to +20 F at refrigerant vapor velocities down to 375 fpm. It was decided that the amazing performance of this system warranted closer study of the percentage concentration of oil in the liquid refrigerant, a closer study of the compressor performance and a photographic study of the oil circulation in the lines.

First examined was the amazing performance of the compressor. In spite of its age it pumped but little oil. The percentage of oil in the liquid refrigerant was 0.6 of one percent or less during all tests in which the needle valve in the line between the compressor crankcase and the suction line was closed. This low rate of oil pumping is comparable to that when a discharge line oil separator is used with most compressors. When oil was injected into the piping system by opening the needle valve, this oil returned to the compressor crankcase in less than 15 min although the crankcase pressure was considerably above that of the suction vapor.

Fig. 10 charts the crankcase pressure and the suction pressure over a 6 hr period of operation. You will notice that the crankcase pressure exceeded the suction pressure by 13 psi shortly after start-up. This pressure difference increased to 27 psi about one hr after start-up then slowly decreased until the pressure difference was

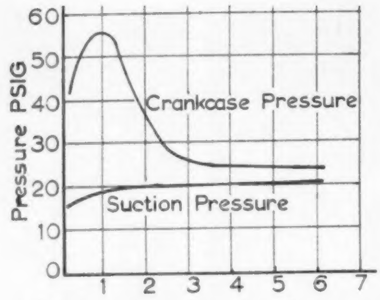


Fig. 10 Crankcase and suction pressures as related to hours of operation

only 3.0 psi after six hr of operation. No noticeable difference in crankcase oil level occurred during the period.

In order to compare the flow of oil in the suction line of this system with that of the previous study, the "P" shaped trap was substituted for the long turn ell and photographs were taken both of it and the horizontal glass sections. The photographs of the glass sections showed little that is not shown here in those of the trap; therefore only the photographs of the trap are reproduced here. These photographs were for tests with the needle valve between the crankcase and the suction line closed.

The concentration of oil in the liquid refrigerant did not exceed 0.6 of one percent by weight. Three tests were run at vapor velocities in the suction line respectively at 400, 480 and 670 fpm. The suction pressure was maintained at approximately 22 psig (approximately 22 F) and at the trap the vapor was superheated approximately 40 F above the saturated condition during all tests. These tests will be presented as Tests 5, 6 and 7.

Test No. 5 Fig. 11 reproduces a photograph of the unusual flow pattern in the trap when the suction line vapor velocity was 400 fpm. The photograph was taken after more than three hr of continuous operation. Oil drops appeared in the horizontal leg of the trap but these drops were stationary. Above these drops the line was completely clear showing no indication of an oil mist. A still pool of oil about ⅜-in. thick lay at the bottom of trap. A slight fogging of the glass appeared at the bottom of the vertical leg but almost immediately after the bend the vertical leg was entirely clear. The system was operated for about three additional hours with no apparent change in crankcase oil level nor oil quantity in the pool at the bottom of the trap. Since the concentration of oil in the liquid refrigerant was 0.6 of one percent it must be concluded in this case that this oil traveled as a transparent colloidal dispersion.

Test No. 6 Fig. 12 shows the flow pattern in the transparent trap when the suction line vapor velocity was 480 fpm, with suction temperature and superheat approximately the same as in Test 5. The

(Continued on page 98)

Flow pattern with low oil quantity in circulation. Fig. 11 Vapor velocity 400 fpm; Fig. 12 Vapor velocity 480 fpm; Fig. 13 Vapor velocity 670 fpm

FIG. 11

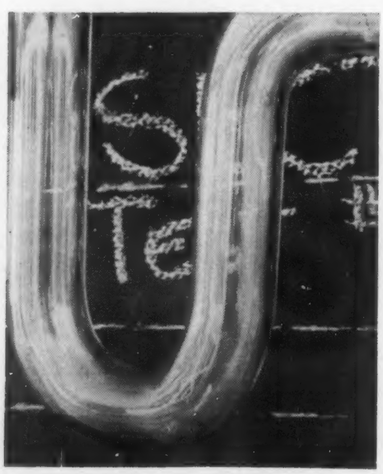


FIG. 12

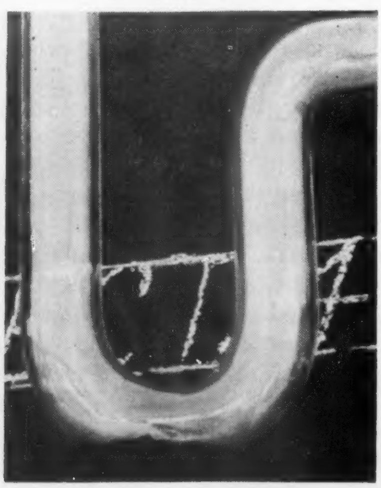
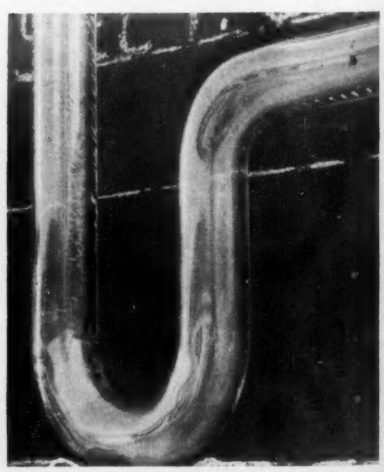


FIG. 13



A salute to
Two fine men

ARTHUR J. HESS

The inevitableness of change is something that usually becomes more and more apparent to most of us as we grow older in life. Many of these changes make little impression on us except when we pause on occasion and observe their cumulative effect. On the other hand, there are changes that are very noticeable to us with profound effect on our lives and activities.

Such changes can occur in organizations such as ours, and one has happened in ASHRAE. This is the change in the Executive Secretaryship that has resulted in the elevation of A. V. Hutchinson to Executive Secretary Emeritus and the assumption of the office of Executive Secretary by R. C. Cross.

The change, of course, will place Mr. Cross in the position of active management of the Society business affairs, under the Officers and Board of Directors, as provided by the By-laws.

Mr. Hutchinson will become an advisor to the Officers, the Executive Committee and the Board of Directors, where his many years of experience can be drawn upon to provide advice and information toward a better Society operation.

Members of the former ASHAE will miss Mr. Hutchinson's active hand on the throttle, for he was in the cab many more years than most of us can remember. Thirty-seven years of his life were spent by this dedicated and devoted man in the work of the Society, and it is the hope of your President that those of you who have dealt with him, or who know him will personally express your appreciation to him for this wonderful service. In his thirty-seven years of service, he assisted in and witnessed the growth of ASHAE as a small group into a large well recognized technical society with members over the entire free world.

Many innovations in Society operation were sponsored by Mr. Hutchinson and he carried out practically all the directives and changes proscribed by the Officers and the Board. Probably the most important contribution, among the many he made, was his work on the "Guide" which he built up into the "Bible" of the Industry and one of the most respected publications of any technical society.

To Mr. Hutchinson we owe much more than we can say in words, or do in deeds.

One deed we can perform, however, is to show our respect for his fine performance by selecting a man of capability to take over the throttle and such a man we have in Mr. Cross, who is well known to members of the former ASRE, where he has been Executive Secretary for the past five years.

Members of the former ASHAE will recall him as a Past Chairman of the Research Committee, a most important post in that Society. This experience in both Societies will stand him in good stead, but no Executive Secretary can function effectively without the cooperation of all the members. Please give him yours. If you have any suggestions, he has good ears, too.

I close with a salute to two fine and wonderful men.

first annual meeting, June 22-24

ASHRAE At Lake Placid

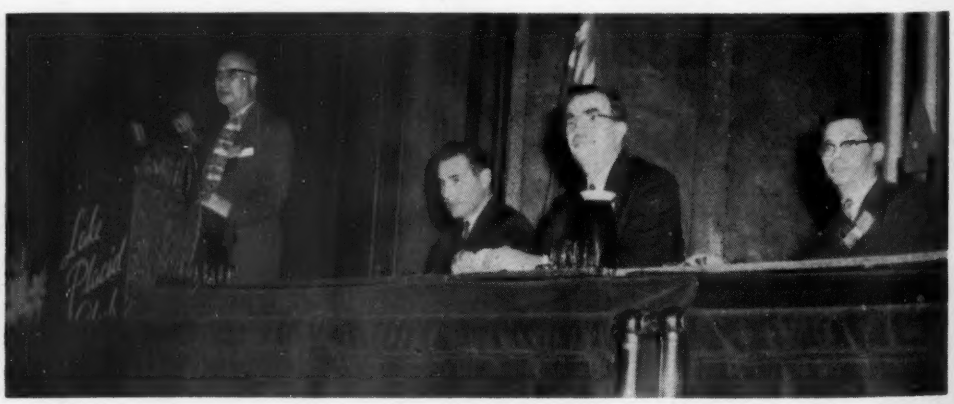
Together with Henry Torrance and M. F. Blankin, senior-attending, and numerous other Past Presidents of the two precedent societies, 775 members and guests converged at the Lake Placid Club for the first of the annual meetings of ASHRAE. A notable occasion in many respects, this meeting included an unusuallv heavy technical program consisting of eight Technical Sessions, three Conferences and six Forums.

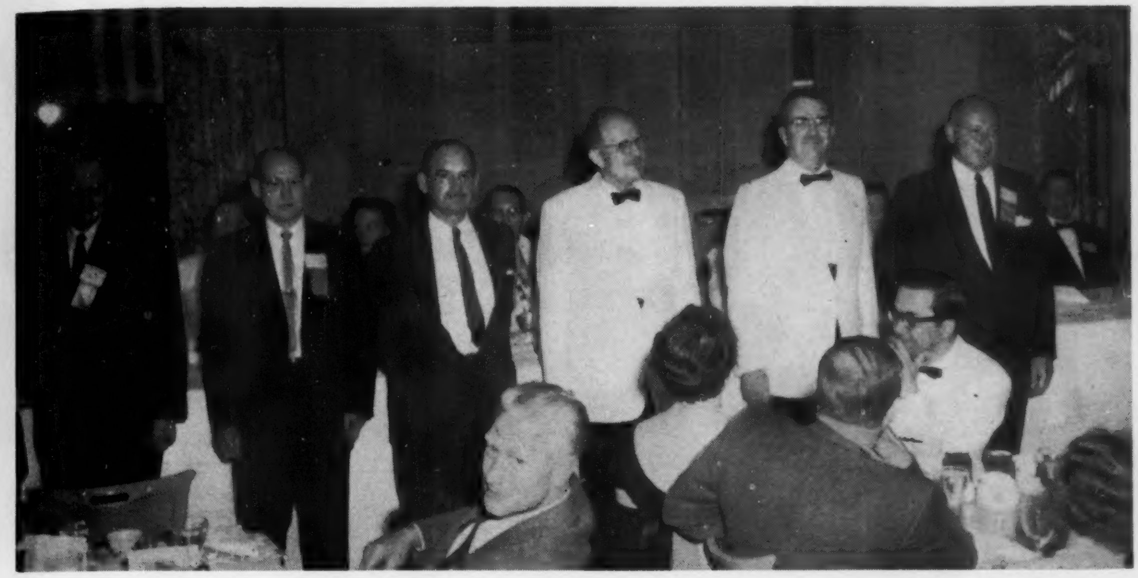
Arthur J. Hess, who has served as President of ASRE and was the last President of ASHAE, succeeded Cecil Boling as President of the Society. Other officers installed were: D. D. Wile, First Vice President; W. A. Grant, Second Vice President; R. H. Tull, Third Vice President; J. Everetts, Jr., Fourth Vice President; F. Y. Carter, First Treasurer; and J. H. Fox, Second Treasurer.

Professor H. M. Hendrickson was presented with the Wolverine Award for his article, "Saline Water Conversion by Freezing," as published in REFRIGERATING ENGINEERING, August 1958. Recipients of the Klixon Award were H. O. Spauschus and R. S. Olsen for their paper, "Gas Analysis – A New Tool for Determining the Chemical Stability of Hermetic Systems" (RE, February 1959).

At various committee meetings, held prior to and during the meeting, the important work of rearrangement of personnel and redefinition of methods and objectives was carried out. The Board of Directors announced that, effective July 1, A. V. Hutchinson became Executive

Fourth Vice President J. Everetts, Jr., was in charge of the Sixth Technical Session. H. P. Harle was Chairman and speakers included Past President C. M. Ashley whose topic was noise in refrigeration and air conditioning systems and B. H. Marvet, experimental study of grille noise characteristics.





16 Past Presidents of either ASHAE or ASRE, or both, received acclaim at the Annual Banquet. As shown: A. J. Hess, E. R. Queer, J. E. Haines, L. N. Hunter, L. E. Seeley, A. E. Stacey, G. L. Tuve, M. F. Blankin, Cecil Boling, Henry Torrance, Jr., Crosby Field, B. H. Jennings, J. G. Bergdoll, Jr., L. Buehler, Jr., C. M. Ashley, H. F. Spoehrer

Secretary Emeritus. Mr. Hutchinson, associated with ASHAE since 1922, became Executive Secretary of that society in 1950 and has served similarly for ASHRAE subsequent to the merger. Robert C. Cross, Executive Secretary ot ASRE for five years prior to the merger, is now Executive Secretary of ASHRAE.

Social Program included the Welcome Luncheon, at which the new officers were installed, the Annual Banquet and golf tournaments and sightseeing trips to local points of interest and scenic attractions. Although several events had to be rescheduled because of inclement weather, none were omitted.

The next meeting of ASHRAE will be in Dallas, February 1-4, concurrently with the 2nd Southwest Heating and Air Conditioning Exposition.

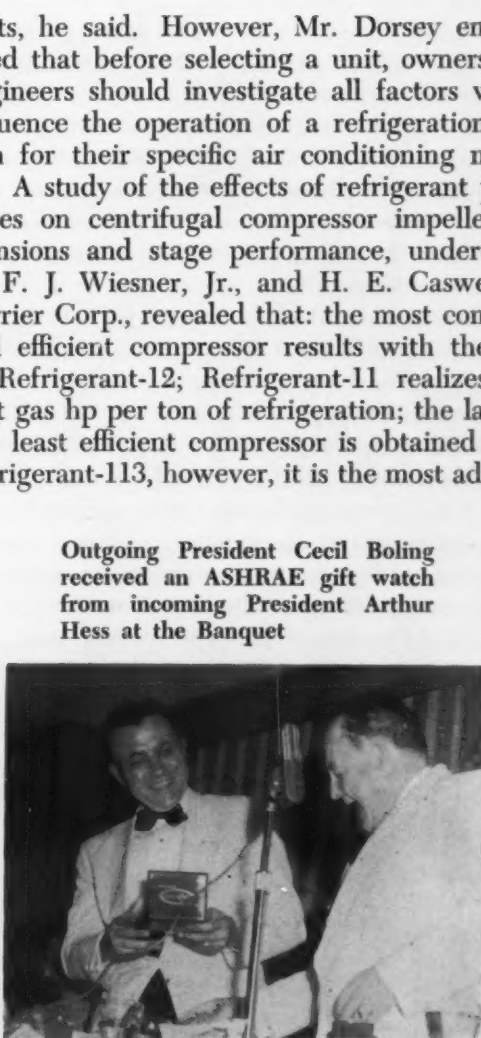
AT THE TECHNICAL SESSIONS

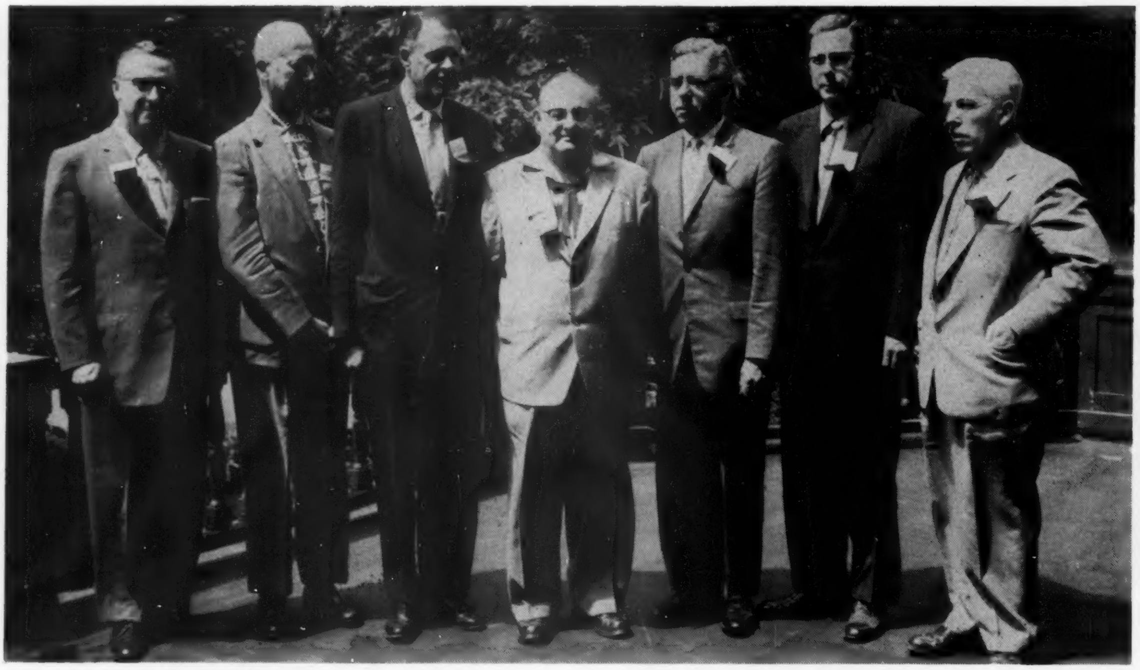
Virtually all areas of interest to ASHRAE members were covered in the broad and comprehensive technical program of eight Technical Sessions, three Conferences and six Forums.

Although turbine-driven centrifugal refrigeration systems with steam condensers are about 25% higher in operating weight than absorption machines, this does not affect the overall cost in most cases, W. G. Dorsey, Jr., of Worthington Corp. asserted. First cost of turbine-driven centrifugals, including steam condenser, cooling tower and condenser water pumps is generally lower than for absorption units, he said. However, Mr. Dorsey emphasized that before selecting a unit, owners and engineers should investigate all factors which influence the operation of a refrigeration system for their specific air conditioning needs.

A study of the effects of refrigerant properties on centrifugal compressor impeller dimensions and stage performance, undertaken by F. J. Wiesner, Jr., and H. E. Caswell of Carrier Corp., revealed that: the most compact and efficient compressor results with the use of Refrigerant-12; Refrigerant-11 realizes the best gas hp per ton of refrigeration; the largest and least efficient compressor is obtained with Refrigerant-113, however, it is the most adapta-

Outgoing President Cecil Boling received an ASHRAE gift watch from incoming President Arthur Hess at the Banquet



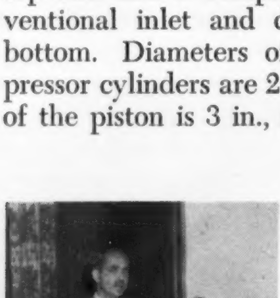


Newly-installed officers of ASHRAE: First Treasurer F. Y. Carter, Fourth Vice President J. Everetts, Jr., Second Vice President W. A. Grant, President A. J. Hess, First Vice President D. D. Wile, Third Vice President R. H. Tull, Second Treasurer J. H. Fox

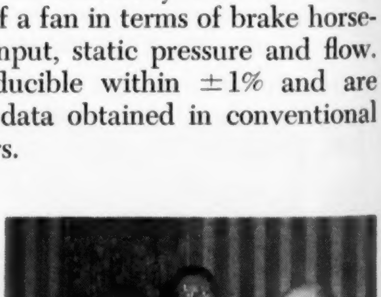
ble for direct motor drive, since other refrigerants require either speed increasing elements or high speed turbines. This advantage of Refrigerant-113 results in its use for this load range despite the fact that its overall performance does not equal that of other refrigerants.

The free-piston engine compressor, combining power generation and vapor compression functions in a single unit, may overcome those problems of first cost, operating and maintenance costs and noise level which have been deterrents to general acceptance of the conventional internal combustion gas engines as an air conditioning power source. R. J. McCrory, R. W. King and J. H. McNinch described such a unit developed at Battelle Memorial Institute – a free-piston refrigerant compressor with a two-stroke cycle combustion chamber on the top end and a compressor cylinder with conventional inlet and discharge valves on the bottom. Diameters of both power and compressor cylinders are 2¾ in. and nominal stroke of the piston is 3 in., resulting in nominal displacements of 17.8 cu in. Operating frequency is 1500 cpm with a condenser saturated temperature of 110 F; refrigeration capacity is 3 tons. The authors pointed out that considerable work in the laboratory and field are required to improve performance and decrease operating cost.

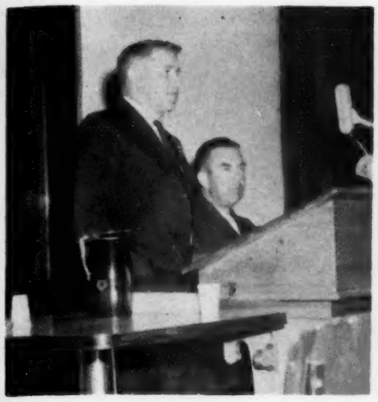
An automatic computer for fan testing using nozzles or orifices, extended successfully to include rapid automatic computation and machine plotting of fan performance curves accurately, was reported by C. H. Pountney, Jr., and D. W. Skipworth, Viking Air Products Div, National-U.S. Radiator Corp. With this apparatus complete fan performance determinations are made in 20 min instead of the approximate 4 hr normally required for testing and calculations. Performance at any desired speed is plotted automatically over the entire operating span of a fan in terms of brake horsepower or watt input, static pressure and flow. Data are reproducible within ±1% and are within ±3% of data obtained in conventional fan-test chambers.



R. S. Ash spoke on evaporative cooling for the common storage of fruits and vegetables at the Fifth Technical Session



Senior - attending Past Presidents M. F. Blankin (ASHAE) and Henry Torrance, Jr. (ASRE) received an ovation at the Annual Banquet



At the Seventh Technical Session F. F. Trunzo discussed the repeated scrape abrasion testing of enameled wires in gaseous and liquid refrigerants, with Chairman J. W. May in charge. At the same session, H. M. Elsey had the estimation of the water content of certain dried but uncharged hermetic compressors as his topic

Two air-filter media were evaluated by their effectiveness in reducing human sensory irritation resulting from Los Angeles smog in a study conducted by N. A. Richardson and W. C. Middleton of the University of California. Much of the testing was done with activated carbon filters varying in air detention time between 0.032 and 0.0030 sec. The authors found that a statistically significant reduction in sensory irritation was accomplished when the smog was passed through activated carbon filters having air detention times at least as short as 0.0030 sec. Differences in effectiveness of activated carbon filters relating to variations in air detention time between 0.032 sec. and 0.0030 sec. were not statistically significant; but ratios between corresponding irritation levels in filtered and non-filtered atmospheres indicated a trend of decreasing effectiveness as air detention time in the filter bed was reduced. Effectiveness of activated carbon in removing oxidants, a function of air detention time, was not improved much by increasing the detention time beyond 0.032 sec., falling off at an increasing rate as detention time was decreased below this point. The study further disclosed that particulate material is not directly related to the occurrence of sensory irritation and that sensory irritation is highly related to oxidant level but only moderately related to temperature.

W. G. Colborne, Assumption University of Windsor, and W. C. Moffatt, Royal Military College of Canada, who presented two papers on chimney design and performance, first discussed fundamentals of chimney performance from a theoretical viewpoint and substantiated these theories with data obtained from laboratory tests of aluminum chimneys. A general chimney performance equation was developed which may be applied to any chimney. Effects of inlet temperature, insulation, chimney height and infiltration on chimney efficiency were analyzed and justified by examination of the equation. It was found that the effect of temperature on chimney performance was not readily predictable and that increasing the height/diameter ratio will normally reduce the efficiency. However, the magnitude of the efficiency drop will depend to a large extent on the heat transfer characteristics of the chimney wall.

In the second part of the study, the authors suggested a practical design method for sizing of chimneys, not limited to any specific size. This design method yields the chimney diameter required, based on a given set of conditions, which will result in a chimney of maximum efficiency. Then the actual draft which will be obtainable under the same set of given conditions is determined. If the actual draft found is not sufficient, the height or inlet temperature of the chimney must be increased. On the other hand, if the draft is greater than that required a draft regulator may be used. This design method is based on steady state conditions and

R. H. Tull was in charge of the Fifth Technical Session for which R. S. Buchanan was Chairman and A. G. Wilson, who discussed condensation between the panes of double windows, R. S. Ash (the evaporative cooling for the common storage of fruits and vegetables) and J. W. Zahradnik (controlled atmosphere apple storage process) were speakers

no account is taken of the effects of infiltration and wind.

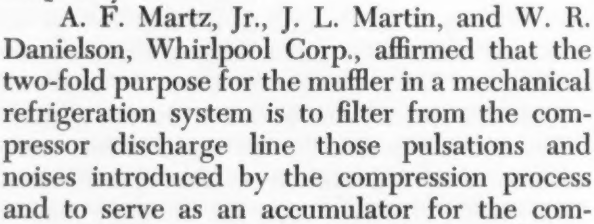
"Best way to get rid of noise is to design it out," advised E. A. Baillif and James P. Laughlin of Whirlpool Corp. They explained that noise is generated by a number of basic physical processes and can be eliminated frequently or reduced by: redesigning the noise producing devices; placing the machine on an appropriate mounting; adding mufflers, filters or dampeners to absorb, block or dampen the noise; or modifying the device to change its noise characteristics to make it less objectionable. The authors concluded that where design for acoustical improvement must be secondary to appearance or performance, it is possible to reduce noise to acceptable limits by proper use of acoustical materials.

Professor R. C. Binder, Purdue University, reported on the results of an investigation of machine noise problems and reviewed methods which are applicable to the study of noise from small compressors used on household refrigerators. Preliminary tests indicated that annoyance is caused by high frequency components, above about 7,000 cps, and by discrete frequency components. The usual human response is to accept the more familiar low frequency sound more readily than the less common high frequency sounds.

A. F. Martz, Jr., J. L. Martin, and W. R. Danielson, Whirlpool Corp., affirmed that the two-fold purpose for the muffler in a mechanical refrigeration system is to filter from the compressor discharge line those pulsations and noises introduced by the compression process and to serve as an accumulator for the compressor so that it does not backload. A design method based upon acoustical theory yielded a muffler which accomplished both objectives. This muffler attenuates in the range of frequencies for which those equations specify a substantial transmission loss. The magnitude of the transmission loss depends not only on the muffler design but also upon the existence or non-existence of standing waves in the tube into which the muffler discharges.

That causes of oscillations are not fully understood is the reason for the lack of success

Nearly 800 members and guests registered here



For the best paper on motors and controls, H. O. Spauschus and R. S. Olsen received the Klixon Award. To Professor H. M. Hendrickson for the

of suppression techniques, C. F. Speich and A. A. Putnam of the Battelle Memorial Institute declared. The oscillation problem has been further complicated in recent years by the use of smaller, more compact heating units placed nearer to the living quarters of residences. In this paper, fifth in a series of reports on results of a research program, two items related to single-port burners which require further study were revealed. One is the physical mechanism by which the vortices are shed from the burner port; the other, a study in more detail of the coupling effect between the periodic variation in heat release and the pressure oscillations. The authors called to the attention of their audience the advantage of compiling information systematically on various arrangements of burner face at port level and the conditions under which they oscillate, to arrive at a practical set of data which would give a designer a feeling for the actual changes that result from various changes in operating parameters.

Reporting on a study of solar radiant gains through directional glass exposure, R. D. Cramer and L. W. Neubauer, University of California, asserted that inside screening devices which hang flat against the glass and have smooth surfaces are better barriers against radiation than those which hang away from the glass. They stressed the importance of intercepting solar radiation before it enters a structure, rather than afterwards. However, they pointed out that these results are applicable only in areas where radiation values and temperatures are high and humidities are low.

A simple and accurate method of load calculation described by W. B. Drake, Lockheed Aircraft Corp., Harry Buchberg and D. Lebell, University of California, in the first of a two-part presentation, uses machine-computed data

best technical paper published in REFRIGERATING ENGINEERING went the Wolverine Award. Presentations by President Hess

that can be tabulated in advance for the determination of heat fluxes through structural sections. The data tabulated are independent of boundary conditions and directly applicable to any situation.

In the second paper, the capabilities of an ac network analyzer in handling thermal network problems were reported. The steady-state sinusoidal method of load calculation is adapted as a means of utilizing previous electric analog experience and of providing the designer with a simple calculation tool. The authors concluded that use of an ac network computer would be an economical way to compute transfer functions of all typical constructions in use.

K. R. Solvason, National Research Council, Canada, commented on a large-scale wall heat-flow measuring apparatus – built up 8 x 8 ft wall sections – which were tested to determine heat transmission coefficients under steady-state conditions and with periodic variation in cold side temperature. This apparatus provides an accurate means for obtaining steady-state heat flows or conductances through built-up wall sections, windows and doors. The test wall was exposed to controlled temperature surroundings, as well as to controlled temperature air; thus, convective and radiant components of surface conductances were evaluated. Transient response of wall sections and effect of moisture movement induced by cycling temperature can be evaluated, and the apparatus can also be adapted to general calorimetry tests.

When outside temperatures are lower than inside condensation will ultimately occur on the inside surface of the outer pane of double windows if the gain in water vapor to the window space is greater than the loss, thus observed A. Grant Wilson and E. Nowak, National Research Council of Canada. Vapor transfer as a result of air flow will depend on the total pressure difference across the window and the relative resistance and distribution of cracks around inner and outer panes, as well as psychrometric conditions. However, when air flow resistance of the inside pane is sufficiently higher than that of the outside pane and has openings around the outside pane located at the top and the bottom of the air space, the air space can interchange air with the outside even with inside pressures greater than outside. Such venting of space, the authors summarized, can be used effectively to prevent condensation between the panes if the amount of outside air interchange is large in relation to the air flow to the space from inside.

Improvement of common storage of fruits and vegetables is effected through use of the principle of evaporative cooling, Robert S. Ash, International Metal Products Co., declared. In this way, high humidity to prevent shrinkage and lower temperature to reduce respiration are achieved, with the additional benefit of fresh air to carry away ripening gases and to prevent odor.

With a controlled atmosphere of 37 F (±1½ F), a relative humidity of 85-90% and an atmosphere of 3% oxygen, 5% carbon dioxide and 92% nitrogen and miscellaneous inert gases, it is possible to preserve the quality of apples for 6 to 8 months on a commercial basis, reported J. W. Zahradnik of the University of Massachusetts. The exact composition, however, will depend on the amount of air exchange during loading.

C. M. Ashley of Carrier Corp. discussed proposed ASHRAE standards for the measurement of sound from equipment. He discussed the various sources of sound, including sounds from mechanical equipment as well as poor building construction, improper sound treatment and other factors which allow undesired sound to reach ears of occupants of a building.

Analyses of chimney design and performance were presented by Professor W. G. Colborne and W. C. Moffatt at the Second Technical Session. Chairman was G. B. Priester

S. J. Williams was Chairman of the First Technical Session where compressors were discussed. (Right) W. G. Dorsey, Jr., whose topic was turbine-driven centrifugal refrigerating systems. (Left) R. J. McCrory, free piston compressor in an air conditioning system

Society standards are being circulated in primary form. Mr. Ashley explained, to enable members to understand them, make suggestions regarding them, and use them when they are finally issued.

A graphic comparison of patterns of octave-band and loudness spectra, showing effects of fin design, grille face velocity and static pressure loss upon the frequency distribution and subjective loudness of grille noise was presented by B. H. Marvet of the Tennessee Valley Authority. Three sample grilles of the return-air type, showing sufficient variation in fin shape and spacing, were examined. However, it was not possible to analyze the effects of such variables as aspect ratio and mass air flow rates.

Oil composition does not affect oil burner noise, concluded W. A. Beach, R. W. Sage, and H. F. Schroeder, of Esso Research and Engineering Co., following an investigation of a variety of fuels. Oil burners used in home heating are not sensitive to fuel composition from a noise level point of view, it was proved. Therefore, changing fuel composition will not reduce burner noise.

Absorption refrigeration is in principle an attractive method for utilizing fuel directly for cooling and is being used in practical applications at the present time. However, Dr. B. J. Eiseman, Jr., of duPont explained that existing adsorption systems have certain deficiencies. The most effective absorbent is completely non-volatile and is readily separated from the refrigerant by distillation. However, the Refrigerant-22 dimethyl ether of tetraethylene glycol system contains advantages which merit careful consideration for all absorption refrigeration applications.

Howard M. Elsey, James B. Kelley and Richard B. Sharpe, Westinghouse Electric Corp., told members of the need for a rapid and practical moisture procedure for checking the dryness of uncharged compressors. Although the centrifuge cold trap method of water content estimating is satisfactory, it is considered too slow for the new internally spring-mounted compressor.

Investigating the effect of pressure on the viscosity of refrigerants, O. W. Witzell and C. Z. Kamien, Purdue University, found that the effect is not great, but a definite increase in viscosity is found with increasing pressure. Unless high pressures are desired, the effect of a small increase in pressure is hardly detectable and only above 6 atm. is an appreciable effect noticed. There is lack of adequate viscosity values for refrigerants; more viscosity values are desired for both vapor and liquid phases.

Development of new and better wire insulation for hermetic applications requires fast test methods which approximate or simulate equipment conditions in actual operation, according to F. F. Trunzo, G. J. Bich, and G. W. Hewitt, Westinghouse Research Laboratories. There are numerous test methods used for evaluating magnet wire insulations for hermetic motors. Results of these tests show that Formvar, polyacrylonitrile, medium functionality terephthalate polyesters, polyesteramide and Formvar-modified epoxies soften considerably and lose almost all of their repeated scrape abrasion resistance after aging in Refrigerant-22 liquid for approximately 20 hr. Polamide and polyurethane modified polyesteramide appear not to be adversely affected in Refrigerant-22 liquid; in fact, repeated scrape abrasion values were improved. Amine catalyzed epoxy is not affected in Refrigerant-22 gas but softens considerably in the liquid.

Window shading material transmission factors for five different materials were determined by R. C. Jordan and James L. Threlkeld of the University of Minnesota, both by solar calorimeter tests and by calculation through independently measured reflectivities and transmissivities of the materials. The sensitivity of the calculated transmission factors to deter-

F. J. Wiesner, Jr., spoke of the effects of refrigerant properties on compressor dimensions at the First Technical Session

At the opening session of the meeting the address of welcome was given by Director R. A. Baker of Region I

mination of the reflectivity and transmissivity was such that experimental variations in these values materially affected the overall transmission values. In those cases where the physical constants could be evaluated reliably the transmission factors were calculated accurately, but where these values were questionable, calorimeter tests were necessary.

Summer heat gains and winter heat losses through a glass-roller-shade combination were investigated for shades of different materials and colors as well as for different type glasses and various glass-shade openings in a study conducted by Necati Ozisik and L. F. Schutrum at the ASHRAE Research Laboratory. Data compiled related to summer heat gains through a glass roller-shade combination reported upon for East, South and West orientations for various hours of the day. Results showed that with an opaque roller-shade, solar heat gains were reduced by lowering the solar absorptance of the surface of the shade on the glass side. The effect of a low emissivity surface for long-wave radiation on the room side of the shade is to reduce heat gain due to solar radiation. A low emissivity surface on the glass side of the shade increases the solar heat gains with a regular plate glass and decreases it with a heat absorbing glass. For an opaque shade with a white surface on the glass side, the solar heat gains are less with regular plate glass than with heat absorbing glass. However, with a dark green shade, heat gains are less with absorbing than with regular plate glass.

Three systems of room air distribution for summer were evaluated on the basis of specific criteria for comfort by J. J. Reinmann, Thompson Products, Inc., Alfred Koestel and G. L. Tuve, Case Institute of Technology, who carried out extensive tests in a room equivalent to a well-insulated living room with exposed walls, operated with surface temperatures simulating outdoor conditions up to 100 F. Results disclosed that the system using round ceiling diffusers was more satisfactory than either high sidewall air supply system or baseboard radial diffusers.

Undertaken by W. F. Hopper, at the ASHRAE Research Laboratory, was a study to find a suitable method of measuring odor adsorption and retention characteristics of surfaces. The test method adopted, an application of the syringe technique, is cited as being satisfactory in evaluating the odor adsorption and retention properties of many surfaces. Test data suggested that maximum odor adsorption rate of fabrics tested during a 24-hour period in odorous air occurred at about 75 F and 50% relative humidity.

At the Domestic Refrigerator Engineering Conference, with F. A. Noll, Manufacturers' Representative, as Presiding Chairman, four discussions were offered covering the design and basic functions required of present day domestic refrigerators. E. Von Arb, Revco Inc., reported on an unusual method of controlling food storage temperature which achieves the minimum temperature variation from a preferred setting and a convenient choice of temperature with assurance of maintaining it regardless of location. The effects of refrigeration temperatures and humidities on the dehydration rates of foods and the growth rate of food micro-organisms were discussed by E. W. Zearfoss and F. P. Speicher, of Philco Corp. Design factors of air flow with regard to evaporator surface and heat load, related to the removal of heat from the frozen storage compartment of the refrigerator by circulation of low temperature air, were examined by C. H. Wurtz, Frigidaire Div, General Motors Corp. Keynoter at this Conference was Colonel C. S. Lawrence, Executive Secretary, Institute of Food Technologists.

Methods and problems involved in providing more comfort for industrial workers were explored at the Industrial Ventilating Conference. G. B. Priester, Baltimore Gas and Electric Co., served as Presiding Chairman at this session. J. H. Clarke, Viking Corp., Div of Union Carbide, discussed the importance of industrial supply air systems, stressing the need of considering the building and manufacturing procedures and processes involved. The need for dust and fume control systems, including de-

(*Continued on page* 104)

A primer of Thermoelectric refrigeration

L. A. STAEBLER
Member ASHRAE

During the past few years, there has been increasing publicity concerning thermoelectricity and its application to refrigeration and electric power generation.

Many articles have been written on this general subject, most of which have been either restricted to some phase of it, or have been too technical for ease of understanding. Thermoelectricity is in the realm of solid state physics, and most articles concerning it require more of a background in physics than is possessed by the average engineer. A simpler presentation is thus presented here.

ADVANTAGES

Fig. 1 illustrates a conventional vapor compression refrigerating system which includes an electric motor, compressor, condenser, throttling valve, evaporator and a vapor refrigerant. The heating and cooling functions of the condenser and evaporator can be interchanged by reversing the direction of refrigerant flow, which cannot be achieved without considerable difficulty and expense. Since the motor and compressor involve rotary and reciprocating motion, wearing of parts and noise may also present a problem. Containing the refrigerant requires a hermetic system which must be leakproof. A further inherent limitation of this system is that it cannot be readily miniaturized to economically provide only a small amount of refrigeration.

Represented in Fig. 2 is a completely electronic refrigerator, without moving parts. The motor, compressor, condenser, throttling valve, evaporator and vapor refrigerant have been replaced by a thermoelectric couple (two dissimilar materials in contact) and a battery or other power supply. Passing a dc current through the couple causes cooling at one of its junctions and heating at the other. Reversing the polarity results in an interchange of the heating and cooling processes; in other words, heat can be directed either way by reversing the flow of current.

Since there are no moving parts, there is nothing to wear out and nothing to generate noise. There is no refrigerant to contain and the tubing has been replaced with electrical wiring. The system can be readily miniaturized, both for low refrigerating capacity and restricted space requirements as may be sought.

Another important advantage, not so obvious, perhaps, is the simple process by which the refrigerating capacity can be modulated to meet the requirements placed on the system. This modulation is accomplished by varying the current flow through the couple, the equivalent of modulating the capacity of a conventional refrigerating system by varying the displacement or the rpm of the compressor.

Fig. 3 presents the possibilities for power generation. Here the thermoelectric effect is being employed in generating electrical energy directly from thermal energy, which should make possible the use of one thermoelectric couple to generate electricity to be fed into another couple, producing refrigeration. This would be the equivalent of absorption refrigeration.

These, then, are the advantages and possibilities of thermoelectric refrigeration that have stimulated so much popular interest and speculation. That this is more than just a passing fancy is shown by the interest approximately 80 companies and several non-profit and government groups have indicated in the product potential of thermoelectricity for cooling and power generation. The military budget for this project is currently $3,000,000 and is expected to be increased to $8,000,000 in 1960 and $40,000,000 in 1961.

Thermoelectric refrigeration is already practical for certain specialty applications, and there are indications that it may someday compete with present methods of refrigeration for household appliances. Of equal importance, however, is the fact that thermoelectric refrigeration creates an opportunity for the development of new products, not practical with conventional methods of refrigeration.

THE SYSTEM

Thermoelectricity is, by definition, the direct conversion of thermal energy into electrical energy, or the reversible transport of thermal en-

L. A. Staebler is Manager, Advanced Development, Appliance Div, Philco Corp. This paper was presented to the Philadelphia Section of the ASRE, April 3, 1959, and the Central New York Chapter of ASHRAE, Syracuse, N. Y., April 15, 1959.

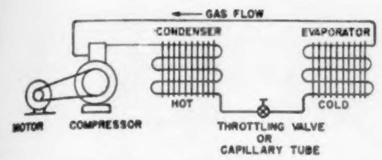


Fig. 1 Vapor compression system

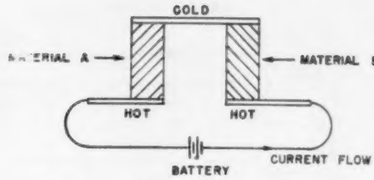


Fig. 2 Thermoelectric system

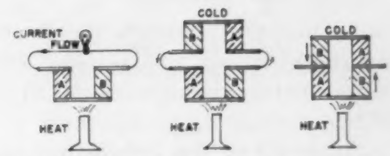


Fig. 3 Electrical power generation

Fig. 4 Seebeck effect

THE GENERATION OF AN EMF BY A TEMPERATURE DIFFERENCE BETWEEN THE JUNCTIONS IN A CIRCUIT COMPOSED OF TWO DISSIMILAR ELECTRICALLY CONDUCTING HOMOGENEOUS PHASES. ($\Delta E = S\Delta T$)

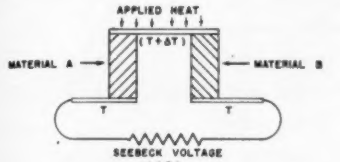


Fig. 5 Peltier effect

THE REVERSIBLE ABSORPTION OR EVOLUTION OF THERMAL ENERGY AT THE JUNCTION BETWEEN TWO DISSIMILAR PHASES WHICH IS PRODUCED BY THE PASSAGE OF AN ELECTRICAL CURRENT THROUGH THE JUNCTION. ($Q = \Pi I$)

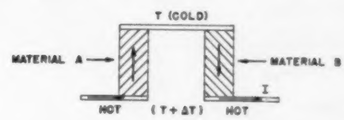
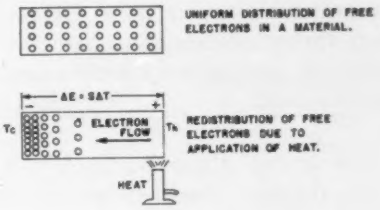


Fig. 6 Electron transport of electrical and thermal energy



ergy by an electric current. If a temperature difference is maintained between the junctions in a circuit consisting of two different materials, an electrical voltage is generated in the circuit. This is known as the Seebeck Effect (see Fig. 4). Common examples of practical applications of this effect are the thermocouple for measuring temperature and the thermoelectric generator used with pilot lights in gas furnaces, which serves as a safety device by closing a solenoid valve in the fuel line when the pilot light goes out. These are examples of power generation by means of thermoelectricity.

The thermoelectric effect of greatest interest to refrigerating engineers is the Peltier Effect (see Fig. 5), in which the passage of a current through the junction of two different materials results in either the absorption or evolution of heat at the junction.

To explain the thermoelectric effect, and why 125 years passed before it could be put to practical use, requires an understanding of the mechanisms involved in an interchange of thermal and electrical potential energy and the characteristics of thermoelectric materials which make this energy interchange possible.

Materials, such as metals, contain a certain distribution of electrons that are free to move in response either to a temperature gradient or to an electric field. Thus, if heat is applied at one end of a metal rod, it will increase the kinetic energy of the electrons at this point and will consequently produce a net flow of electrons toward the cold end, transporting heat in so doing. Since each electron also carries an electrical charge, this flow of heat is accompanied by an electrical current. See Fig. 6.

This, then, is the key to the thermoelectric phenomenon. Because the flow of electrons is involved in transport of both heat and electricity, it is possible to transport heat directly by means of an electrical current or, conversely, to cause a flow of electrical current through the application of heat.

REFRIGERATING SYSTEM ANALOGIES

Fig. 7 shows certain similarities or analogies between the vapor compression refrigeration system and the thermoelectric refrigeration system. The key to the successful operation of each system is in providing the means for obtaining a change in "energy level" relationships at the hot and cold sides of the system. In the case of the vapor compression cycle, this is made possible through use of a throttling valve between the condenser and evaporator. Without this valve, there would be a constant pressure and a uniform refrigerant enthalpy (energy level) throughout the system and no heat pumping would occur. The same may take place in the thermoelectric circuit.

If materials A and B are identical, the energy level of the electron gas would be the same throughout the system and there would be no heat pumping. However, by selecting materials with different available electron energy levels, the electron "gas" flowing across the barrier or "junction" must undergo an energy change which results in either the absorption or rejection of heat energy at the junction, depending on the direction of the current flow. Fig. 8 illustrates simplified energy level diagrams for the two systems.

Considering five major aspects of thermoelectric refrigeration, this paper first presents the advantages of the system. It includes a non-technical explanation of the thermoelectric process with analogies to well known principles of mechanical refrigeration. Moving further into the subject, design and manufacturing problems are discussed, and economic considerations are analyzed. On the basis of this information suggestions are made for present and future applications of thermoelectric systems.

PARAMETERS

The concept of "energy level" is important to an explanation of thermoelectric refrigeration. For the best operation, the difference in energy levels in the two materials should be as great as possible. A discussion of the parameter of thermoelectric materials which is related to the energy levels, in addition to other parameters, which characterize the merit of various materials, follows. Fig. 9 shows the similarities between these parameters and corresponding characteristics of compressor design and performance.

The first of these parameters is the thermal conductivity, K, of the material, which results in backward flow of heat through the couple. Such loss should be kept to a minimum by striving for a low K.

Analogy: This is similar to the backward flow of gas in a compressor due to piston blow-by and valve leakage.

The second is the electrical resistivity, ρ, which determines the I^2R losses. To limit this loss, ρ should be of a low value.

Analogy: This is similar to the loss in compressor pumping capacity due to mechanical friction and other factors which superheat the suction gas in the compressor.

The third parameter is the thermoelectric power, S, or Seebeck coefficient, which describes the energy difference of the electrons in the two materials in contact. It is described mathematically as $S = \Delta E/\Delta T$ and is equal to the rate of change of the Seebeck voltage with temperature. More simply, it may be described as the energy transported by electrons pumped for a given temperature difference. A high thermoelectric power is essential to good performance.

Analogy: A parallel concept in compressor performance is the mass (number of molecules) of refrigerant gas pumped by the compressor per unit volume of

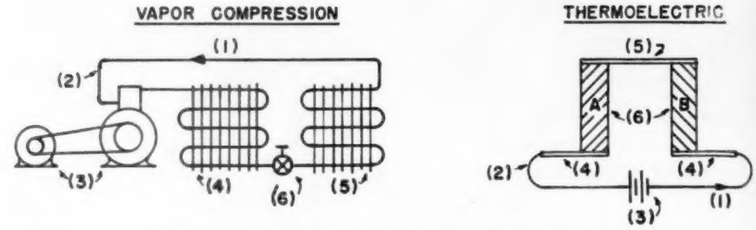
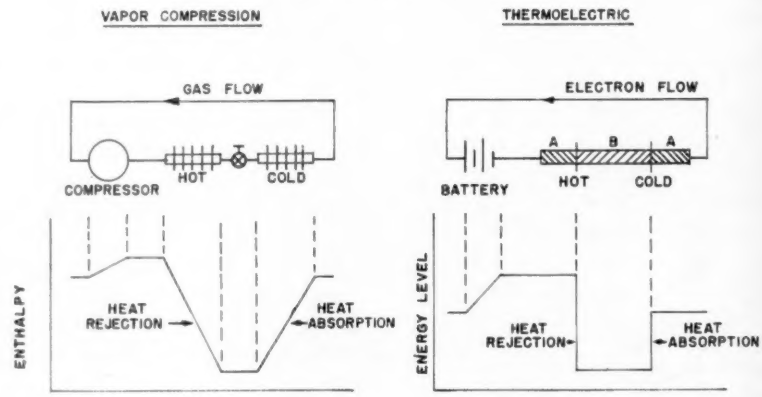


Fig. 7 Refrigeration system analogies

(1) Refrigerant gas	(1) Electron gas
(2) Leak-tight tubing	(2) Electrical conductors
(3) Motor-compressor	(3) Battery
(4) Condenser	(4) Hot junction
(5) Evaporator	(5) Cold junction
(6) Throttling valve	(6) Energy level relationships
(7) Motor losses	(7) Battery losses
(8) Compressor losses	(8) Losses in thermoelectric materials
(9) Reverse cycle valve	(9) Reverse cycle switch
(10) Capacity modulation mechanism	(10) Capacity modulation by varying electric current

Fig. 8 Energy level diagrams



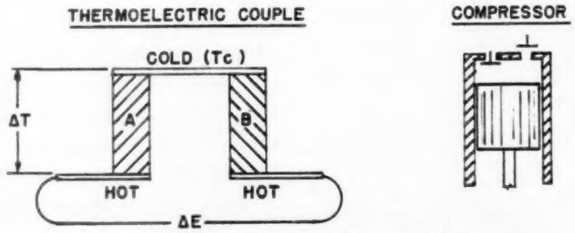


Fig. 9 Analogies between thermoelectric material parameters and compressor characteristics

(1) Thermal conductivity, K (results in backward flow of heat)	(1) Losses due to gas leakage past piston and valves
(2) Electrical resistivity, ρ (results in I^2R losses)	(2) Loss in pumping capacity due to friction and other factors which superheat the suction gas in the compressor
(3) Thermoelectric power $S = \Delta E/\Delta T$	(3) Pumping efficiency as affected by head clearance
(4) Figure of merit $Z = S^2/\rho\text{-}K$	(4) Volumetric efficiency as affected by (1), (2), (3)
(5) Maximum temp. difference $\Delta T_{max} = \frac{1}{2} Z T_c^2$	(5) Maximum pressure difference (or max. compression ratio) as affected by volumetric efficiency and suction pressure.

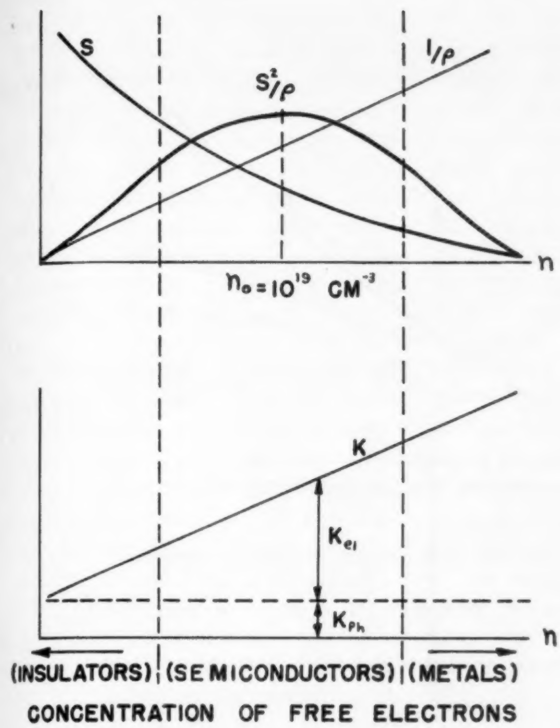


Fig. 10 Effect of free electron concentration on the parameters of thermoelectric materials (from A. F. Ioffe) $Z = S^2/\rho K$

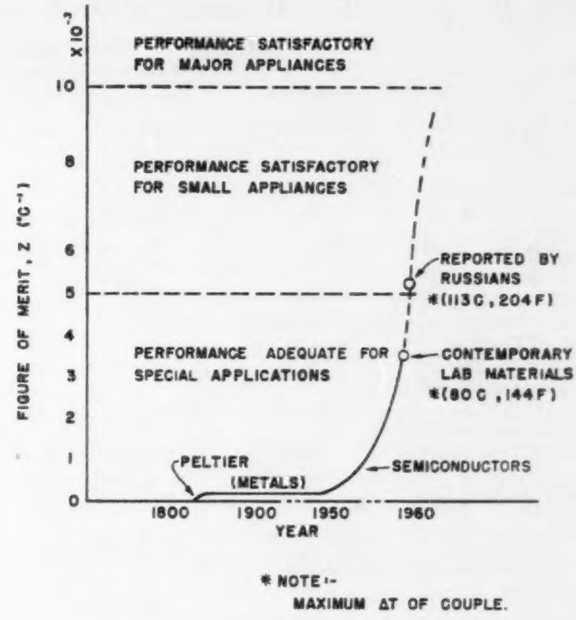


Fig. 11 Progress in thermoelectric refrigeration

piston displacement, as influenced only by the reexpansion losses due to head clearance. For a high pumping efficiency, the head clearance should be as low as possible.

The figure of merit, Z, which involves the three parameters previously discussed, is used for describing the merit of a thermoelectric material, and is defined mathematically as $Z = S^2/\rho K$. It should be noted that S, ρ and K are interrelated and are all dependent on the concentration of free electrons. Other factors are involved in the maximization of the figure of merit; however, these are beyond the scope of this presentation. See Fig. 10.

Analogy: A similar concept in compressor performance is the volumetric efficiency as affected by all three characteristics already discussed, i.e., piston blow-by and valve leakage, friction losses contributing to gas superheating, and reexpansion losses.

A useful relationship may be derived from the figure of merit. This is the maximum temperature difference that can be developed under no-load conditions between the hot and cold junctions of a couple. It is defined as $\Delta T\,Max = \frac{1}{2} Z T_c^2$, where T_c is the cold junction temperature in degrees Kelvin.

Analogy: This is similar in concept to the maximum pressure difference — or maximum compression ratio — obtainable in a compressor, also in an unloaded condition, and is similarly dependent on the volumetric efficiency and the suction pressure.

SEMICONDUCTORS

The various thermoelectric materials will now be examined to determine the reason for the recent acceleration in development. In this connection, refer to the chart of Fig. 11 which shows the progress in thermoelectric cooling since 1834. Pure metals have an inherently low thermoelectric power. Also the relationship between thermal and electrical conductivity is fixed. Because of this, metals are not particularly suitable materials for thermoelectric refrigeration, and progress was at a standstill until post-war advances in solid state physics gave us a new class of thermoelectric materials known as "semiconductors," which have properties particularly adapted to thermoelectric applications.

The term semiconductor is almost self-explanatory. Metals are good heat and electrical conductors due to a plentiful supply of "free" electrons. Insulating materials, as the name implies, are poor conductors because their electrons are tightly bound. A semiconductor, therefore, is a material with an electrical and thermal conductivity somewhere between that of a conductor and an insulator. However, its thermal conductivity is due to the properties of both conductors and insulators. That is, in addition to heat carried by electrons, thermal energy is also transported by phonons or lattice vibrations, the vibration of the atoms. This is the method of heat transport in an insulator.

The total thermal conductivity of a semiconductor is thus made up of two components: electronic and non-electronic. Independent adjustment of the lattice vibration component may be accomplished without affecting either the electronic component of the thermal conductivity or the electrical conductivity itself. Considerable improvement in the figure of merit is thus possible in semiconductors through an independent adjustment of the thermal conductivity, K. In metals, thermal conductivity K and electrical resistivity ρ are

FIG. 12. HYPOTHETICAL APPLICATION DATA

Design Conditions	Air Conditioner	Small Refrig.	Small Ice Maker
T_H (Hot)	125 F	120 F	80 F
T_c (Cold)	45 F	35 F	15 F
Btu per hr	12,000 (1-ton)	150	50
Vapor Compression			
C.O.P.	2.3	1.0	0.5
Watts Input	1,500	45	30
Est. Mfg. Cost	$100	$25	$20
Thermoelectric			
C.O.P.	0.4	0.4	0.6
Watts Input	8,600	110	25
No. of Couples	4,000	50	15
Cost of the Material (10c per couple)	$400	$5	$2
Cost of Structure (40c per couple)	$1,600	$20	$6
Cost of Power Supply	$35	$20	$15
Est. Total Mfg. Cost	$2,035	$45	$23

Assumptions: $Z = 3 \times 10^{-3}$, couples designed for average of max load and max c.o.p., A/L = 1. Costs based on high production quantities and techniques. Present costs much higher.

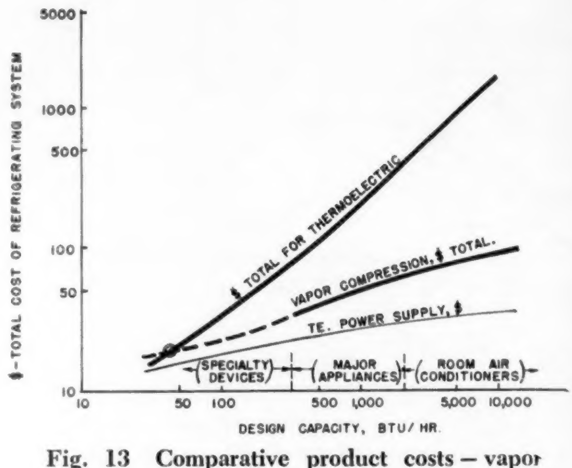


Fig. 13 Comparative product costs — vapor compression vs. thermoelectric refrigeration.

Assumptions:
Total cost per couple, including structure — $0.50
Couples designed for average of max. load and max. c.o.p.
Couple geometry A/L = 1
$Z = 3 \times 10^{-3} (°C^{-1})$

related by the Wiedemann-Franz law, which states that the product $K\rho$ is a constant. This means that K or ρ cannot be independently adjusted, limiting the thermoelectric effect in metals.

In addition, semiconductors are the most promising thermoelectric materials because their concentration of charge carriers (free electrons) are of a magnitude where S^2/ρ is a maximum. See Fig. 10. Semiconductors possess still another thermoelectric advantage. This is due to the fact that electrical and thermal currents may result from a flow of either electrons or positively charged "holes" vacated by electrons. The two types of semiconductors are known as "N-type" and "P-type," respectively. A junction of these two types of material results in an unusually large thermoelectric power. For these reasons semiconductor materials play an important part in making thermoelectric refrigeration a practical reality.

It may be of some interest to note that bismuth telluride, Bi_2Te_3, is presently the most commonly used semiconductor for thermoelectric refrigeration. The N-type material usually has a small excess of tellurium to provide free electrons, or negative charge carriers. The P-type material is likewise bismuth telluride; however, it has a small excess of bismuth to give positive charge carriers. Doping of pure bismuth telluride with impurities can also produce N- or P-type materials.

ENGINEERING PROBLEMS

Appreciation of the manufacturing and engineering problems requires involvement in the design and development of devices. Problems that must be solved include:

Economical production of good thermoelectric materials.

Determination of the best physical configuration of the couple as influenced by considerations of refrigerating capacity, space limitations, cost per couple, cost per Btu and power supply requirements.

Fabrication of the individual couples, involving considerations of cutting to size, plating and soldering.

Assembly of multiple-couple panels to provide the total amount of cooling required. This includes considerations of physical structure, thermal insulation between the couples, heat conduction to attached extended surfaces, and electrical circuitry.

Satisfactory means for efficient removal of heat from the hot junction and rejection of it to the air or other heat sink.

Design of efficient, low cost power supplies to furnish low voltage, high amperage dc output.

ECONOMIC CONSIDERATIONS

As to the economics of the situation, the questions most frequently asked are: How good is thermoelectric refrigeration?; How does it compare with conventional refrigeration in terms of manufacturing cost and cost of operation?; and When will it become competitive to conventional methods of refrigeration?

The question, "How good is thermoelectric refrigeration?", can best be answered in terms of the maximum temperature difference available. Present day materials are capable of reaching a maximum temperature difference of about 145 F in an unloaded condition, which is approximately the temperature difference encountered by the refrigeration system of a household refrigerator in maintaining a 0 F evaporator air temperature in a 110 F ambient. Note, however, that the 145 F temperature difference is obtainable in the thermoelectric system only when the couple is not loaded, i.e., is per-

fectly insulated and not picking up any heat. If a reasonable load is put on the couple, the operating temperature difference may drop to 70 F. Obtaining the desired temperature difference in a loaded condition requires design of a cascade system or provision for water-cooling of the hot junctions. Thus it does not appear that present-day materials are good enough to permit us to build a practical and economical conventional household refrigerator capable of maintaining a zero freezer in a 110 F environment. There are, however, many other appliances and specialty items not requiring such a high temperature difference which can be more readily powered by a thermoelectric system.

The cost of operation is also an important consideration, particularly where a large refrigerating capacity is involved. Thermoelectric couples are, at present, relatively inefficient compared with the vapor compressor system. Estimated roughly, the C.O.P. of the thermoelectric system is perhaps only 10% to 50% of that obtainable from conventional systems. This means, of course, that it may cost 2 to 10 times as much to operate, which would be prohibitive for air conditioners and household refrigerators, but would be of less consequence with the smaller appliances and with specialty items of various kinds.

Present manufacturing costs also present a somewhat discouraging picture. The thermoelectric materials for a single couple with a heat pumping capacity of perhaps three Btu per hour may currently cost about $1.00. Total costs per couple, including fabrication into panels and complete with heat transfer surfaces may therefore be as high as $5.00, not including power supply or controls, when prepared on a laboratory basis. Hand-built samples of thermoelectric refrigerating systems may accordingly cost in excess of $500 for a capacity of 100 Btu per hour. However, improvements in technology and techniques might soon result in a 90% reduction in costs if the volume of sales were sufficient to warrant production on a large scale basis.

Fig. 12 gives hypothetical application data which will aid in bringing the foregoing discussion into sharp focus. Fig. 13 provides additional information concerning relative product costs as influenced by requirements of heat pumping capacity. From these data it will be seen that a thermoelectric system using present day materials is potentially more economic for capacities up to about 100 Btu per hour. With capacities above this value the curves become increasingly divergent and the economics of the situation favor the use of conventional refrigeration systems. Improvements in technology and materials will, however, make thermoelectric refrigeration increasingly attractive.

WHAT OF TOMORROW?

The last question, "When will thermoelectric refrigeration become competitive to conventional refrigeration?", is also answered in Figs. 12 and 13, which show that thermoelectric refrigeration is already competitive for applications and specialty items where the Btu requirements are low, where manufacturing costs and cost of operation are not important, or where conventional refrigeration cannot be used satisfactorily because of space limitations or other reasons. Therefore, the most promising uses for thermoelectric refrigeration in the near future are in the military, for instrument application, and for certain specialty items in the appliance market where only a moderate amount of cooling is necessary. However, as materials improve and manufacturing techniques are refined, thermoelectric refrigeration will become more attractive for application to the major appliances. It is not expected, however, that it will ever be a serious contender in the air conditioner market unless some major break-through occurs in solid-state physics and in engineering technology.

ACKNOWLEDGMENT

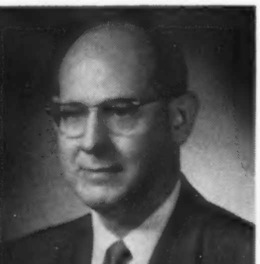
The author wishes to gratefully acknowledge the valuable assistance rendered by Marvin A. Gross, Physicist, and others of the Advanced Development Department of Philco Corporation in the preparation of this article.

Author Staebler, who presented this paper before the ASRE Philadelphia Section, received the Philadelphia Award for the best technical paper of the year, as delivered before that group. Here shown are Philco associates M. Gross, W. H. Mullin (Vice Chairman of the Philadelphia Chapter of ASHRAE), Mr. Staebler, Frank Edwards, L. C. Bastian and D. Scofeeld

Combustion in the heating industry

There was an all-day conference covering various aspects of combustion at ASHRAE Research Laboratory in Cleveland on May 21, 1959. The meeting, under the chairmanship of Malcolm W. McRae, brought together eleven panel speakers, each a specialist in his field, to discuss separate topics of the program. Following these presentations, there was an open discussion of viewpoints by the 100 or so in attendance and the speakers.**

Keynoting the conference, ASHRAE's Research Director cited its purpose to be a search for the most pressing needs in combustion research in the heating field. He mentioned that by far most of the energy for man's use must continue to derive from the combustion process even though nuclear reactions are becoming important as a future source of energy. During the last decade, an enormous amount of research has been carried out relative to the high energy release rates associated with jet propulsion, rockets, and gas turbines, and our knowledge in this field has been enhanced greatly. Unfortunately, the research aspects of combustion in the less spectacular field of heating usage have been neglected. Nevertheless, a large segment of our economy is associated with the use of combustion for heating, using gaseous, liquid and solid fuels. Proper utilization of these fuels is important in many aspects; ranging from the economic to that of air-pollution control.



BURGESS H. JENNINGS*

Burner performance and fuel-oil properties – R. P. Gilmartin,† opening panelist, discussed significant properties of fuel oils, indicating the importance of inherent factors, such as residual carbon, distillation tests, and color tests. He indicated the joint responsibility of petroleum manufacturers and equipment manufacturers in developing a product of maximum utility to the user and reported on the considerable research work that is currently being carried on in the laboratories of many petroleum refiners and also told of the program of research investigation being conducted by the American Petroleum Institute.

R. C. Wright†† continued the discussion and called attention to some problems associated with the character of the fuel as related to burning. He stated: "Number 6 fuel oil (sometimes called 'Bunker C,' and out on the Pacific Coast, 'PS-400') is not normally used for commercial heating, but since its low cost and high heating value makes it an attractive fuel, a few words about it are in order. No. 6 is a black, viscous fluid which requires heating, to condition it for burning. The investment required for suitable heating and pumping equipment makes No. 6 impractical for small automatic heating plants. There is no exact capacity which can be called the minimum practical firing rate for No. 6 fuel, but it is probably somewhere around 25 gph. There are, of course, many smaller units burning No. 6 oil with satisfactory results in a particular plant, and even larger capacity installations where lighter fuels are preferable. Even where adequate heating equipment is available, there is a problem of adjusting the temperature regulators to follow the changing viscosity of the fuel. The commercial standard specifications for heavy fuel oil permit a wide range in viscosity. For example, No. 6 oil may vary from approximately 750 S.S.U. to 8,000 S.S.U. at 100 F. Assume, for example, that for best results in a particular plant, the burning equipment should be supplied with oil at 300 S.S.U. This means that the oil temperature regulator might require adjustment from 135 to 200 F to compensate for the possible viscosity range.

Number 5 oil also requires heating for burning, but the lighter or less viscous grades of No. 5 can be burned cold under some conditions. This borderline condition between hot and cold oil of the same grade has been responsible for many cases of faulty operation and poor combustion. At 70 F, No. 5 fuel can range from about 250 to 2,000 S.S.U. A particular burner may work well with one load of unheated No. 5 oil, but be quite unsatisfactory with a subsequent load of heavier oil. This frequently happens when a user changes suppliers or may even occur between loads from the same supplier. A plant with a small storage tank may work well in the winter time when it is refilled frequently with warm oil from the supplier's tank truck, but give trouble in the spring and fall when demand is light and the longer periods between filling the tank allow the oil to cool. For complete satisfaction, therefore, No. 5 oil, like No. 6 by current standards should be used only where oil-heating equipment is available. This generally requires too great an investment in equipment for small installations.

No. 5 probably gives more trouble from the standpoint of stability than any other grade. There are two kinds of instability. The first is the tendency for deposits to foul heat exchanger surfaces. There are test procedures for measuring this characteristic. A stability test is used by the Navy, but is not part of Commercial Standard specifications. The other form of instability is gravity separation in the storage tank. This is a common problem where No. 5 oil is concocted by a distributor by mixing

* ASHRAE, Director of Research
** Crane Company
† Gulf Research and Development Company
†† Iron Fireman Manufacturing Company

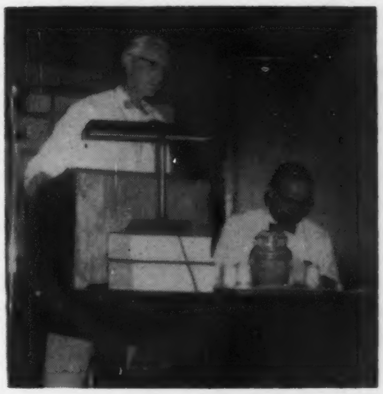
No. 6 and No. 2. These mixtures are frequently unstable, when the separate components are not compatible or the mixing procedure is not adequate. This situation might be corrected by adding to the Commercial Standard specifications the requirement that blending of fuel oils must be done at the refinery from compatible stocks.

No. 4 fuel does not warrant much discussion because its use is rather limited, due to limited availability.

No. 2 fuel oil is the product of most importance for oil-fired residential systems, and is likewise most widely used for small commercial heating. Thanks to our competitive American system of free enterprise, our petroleum industry makes available almost everywhere an unlimited supply of notably high-quality heating oil. My company's experience, and others in the oil burner industry have the same experience, indicates that fuels produced and distributed by major brand name companies is remarkably uniform and high in quality. Obviously, the public benefits more from this competitive situation than from the protection of Commercial Standard specifications, because the present specifications permit much wider variations than occur in the fuel. Occasionally, we find indications of extreme limit or even substandard products in places such as farm co-ops which buy on specification only, and also occasionally we find indications of low quality fuels in public buildings where the purchasing is by specification bid only, but that is generally not the case.

The present relatively broad specification range presents a problem to the burner designer who must design his burner to give acceptable performance with a relatively wide range of fuel characteristics. He could certainly do a better job if he had narrower limits to work with. For example, take A.P.I. gravity. The present limits for No. 2 go down to 26. Only a small fraction of the available fuels on today's market are below 32 A.P.I. gravity, yet our burners are tested by approval agencies with 26 gravity fuel. If the minimum gravity for No. 2 is raised to 32 A.P.I., we might be able to design better burners and build them at less cost.

Viscosity is an even more important characteristic. This determines the rate at which oil flows through a nozzle orifice and has an important effect upon the quality of atomization. Uniform viscosity is of great importance to optimum performance. Present No. 2 standards specify a maximum viscosity of 4.3 kinematic centistokes at 100 F with no minimum limit. The burner could do a better job if the upper limit were reduced to, say, 3.4 centistokes, and a minimum established at, say, 2.0 centistokes. These specific limits represent merely an opinion that might well be investigated by research and testing.



As E. O. Olson addressed the Conference; M. W. McRae presiding

Stability is also an important characteristic of No. 2 fuel and has been a problem. Equipment and appliance manufacturers can do little about it, but instability has been the source of some troubles with small capacity burners and we would like to see something done about it. The stability problem with No. 2 distillate is quite different from that with No. 5 residual. With No. 2, it appears to be a gradual changing of the physical characteristics with the formation of gum and semi-solid constituents in what was originally a clear liquid. This probably results from actual chemical changes, as compared with physical separation such as occurs in the case of No. 5.

Some burners are offenders from the standpoint of atmospheric pollution because they require a warm-up period before completely smokeless operation is reached. Present day standards allow a 15 minute warm-up period before reaching the required minimum smoke level. In my opinion, that is not a good standard because most plants in this size use on-off control and starting is frequent. This is quite different than is the case of the larger plants using modulating controls which keep the burner in almost continuous operation, and have few warm-up periods.

There are burners with combustion heads which do control the fuel and air mixing so that combustion is not dependent upon temperature and no warm-up period is required.

The supply of air is also a burner function. Burners are either forced draft or induced draft, depending upon whether the combustion air is forced into the combustion zone from a blower or is induced by the pull of a chimney or fan located in the vent outlet. The term "forced draft" also has another meaning which should be clarified. Most furnaces and boilers in this range operate with essentially atmospheric pressure in the firebox. The furnace pressure is generally slightly below atmospheric to prevent leakage of products of combustion, but only slightly so to reduce losses due to infiltration of excess air. This furnace pressure is usually a delicate balance and has an important bearing on efficiency of operation. Some boilers operate with sealed fireboxes under pressure. This type of operation is also generally referred to as "forced draft." Firebox pressures may be any amount up to several inches of water, depending upon boiler design from the standpoint of pressure loss through the gas passages and depending upon the design of the venting system.

The presently accepted method for smoke determination might be further developed to establish quantitative measures of carbon effluent in the exhausted products of combustion. Future studies of atmospheric pollution could use such a procedure. The test procedure consists of drawing a specific volume of flue gas through a specific area of calibrated filter paper and comparing the color of the paper with a standard chart. This gives a basis for comparison relative to other burners. Possibly, a little more research with this method would also let us tell with some degree of accuracy just how much carbon one gallon of oil discharges into the atmosphere when producing a No. 2 smoke. Certainly, we have come a long way already. It was only a few years ago that smoke was measured by visual comparison of the discharge from the top of the stack with a chart. These charts were called "Ringleman Smoke Numbers." It is interesting to note that the least smoke visible on the Ringleman scale indicates more smoke than the darkest or No. 9 spot on the Shell-Bacharach scale."

J. G. Partch* called attention to the fact that since 1955, the U. S. Bureau of Mines, at the request of the Oil Heat Institute of America, has published an annual survey of fuel oil quality. The information compiled in this survey is supplied by the various refiners on their own products in accordance with instructions issued by

* Standard Oil Company (Ohio)

the American Petroleum Institute and determined by standard ASTM test methods. With the advent of this survey, it has been easy to study the variation in fuel oil quality throughout the country.

He noted that a number of changes in specifications had been under consideration and discussed these in detail. He then discussed what the refiner can do about making No. 2 oil to meet more restrictive specifications. The refiner has several ways in which he can control the quality of his furnace oil production as far as gravity, viscosity and volatility are concerned, namely crude selection, distillation, cat-cracker operation and blending.

"Crude selection does offer some control. However, crude selection is an economic consideration weighing yield and quality of all products from a given crude with several other factors such as location, transportation, availability, etc. Almost never can a refiner select a crude on the basis of furnace oil quality alone.

"Distillation of both straight run and cat-cracked stocks is an important means of control of furnace-oil quality, but again the determination of the distillation cut points is based not on No. 2 fuel oil alone. This is again a compromise which provides the best yield and quality relationship for the entire distillate product mix. It would be well to mention here the interdependence of these critical properties we have been discussing. For a given virgin stock, the gravity and viscosity, as well as pour point, are determined by the boiling range or volatility.

"Catalytic cracking – a process adopted to improve yield and quality of gasoline – provides components for fuel oil production differing in these critical properties from virgin stocks. Once again, cat cracker operation and distillation cuts of the cracked stocks are not determined by the needs of No. 2 fuel oil alone. To make matters still more complicated, the operating conditions of the cracker are usually varied, depending upon the seasonal demand for gasoline or fuel oil. These seasonal changes usually also affect the quality of the fuel oil blending stocks produced. Here, again, we have a relationship between these critical properties. Cat cracked stocks have a different relationship between volatility on one hand and gravity and viscosity on the other hand than do virgin stocks. This relationship is a function of the cat cracker operating conditions.

"Control of fuel oil quality by blending is the refiner's 'ace-up-his-sleeve.' The stocks which he has available to blend do not just happen but rather have been designed, despite the various necessary compromises, to enable him to produce his specified quality of furnace oil. The fact that most major refiners have their own specifications – narrower than CS 12-48 – which they can meet consistently, speaks well for their ability to blend and for the overall planning of their operations. The Bureau of Mines Survey shows that in 1958, as in previous years, the bulk of No. 2 fuel oils marketed in the U. S. was significantly better than required by CS 12-48. Some tightening of this standard undoubtedly could and should be done. However, the need for these changes should be based on the fact that the burner manufacturers can and will take advantage of closer oil specifications to improve burner design. If there is a need for an industry research program, perhaps it is in the area of designing better burners for better fuels."

Atomization of liquid fuels – E. O. Olson* opened the discussion of this topic by calling attention to the functions performed by the atomizing nozzle to prepare liquid fuel for combustion, noting that atomization of the fuel increases the area exposed to air, thus permitting increased rates of combustion and better control. With a 1.0 gallon-per-hour, 80° nozzle the fuel surface area is increased approximately 3500 times in the atomizing nozzle. Fuel is supplied under pressure to the nozzle, and the nozzle serves as a metering orifice. Finally, the atomizing nozzle discharges the finely divided spray into the combustion chamber in a pattern suited to the particular burner air pattern.

"In most of the nozzles used in combustion applications in which pressure-atomizing, swirl-chamber nozzles deliver a cone spray," stated the speaker, "it was noted that the mechanism of breakup in this type of nozzle is the same as for all pressure atomizing equipment, namely:

A liquid is formed into a thin film, divergent in its direction of travel.

Ligaments break off from the end of the film approximately at right angles to the direction of flow.

Ligaments break up further into droplets by the action of the liquid surface tension and by the resistance of the air through which the liquid is traveling.

Droplet size in a spray varies approximately inversely as the 0.3 power of the pressure.

Droplet size in the spray increases as the spray angle decreases, assuming constant discharge rate.

Droplet size increases with an increase in discharge rate at the same supply pressure and spray angle.

Discharge rate varies as square root of pressure.

"The cone spray nozzle has several advantages over other types of atomizing devices. This type of nozzle is cheap and can be made relatively small in size. It can also be made into a wide range of spray angles from 30 to 100°. This type of nozzle can be made to deliver spray patterns ranging from heavy-center, "solid-cone" nozzles to a completely hollow-cone type of spray.

"The cone spray nozzle of the simplex type has several disadvantages. In the low flow rates the dimensions of the metering passages are very small, thus presenting a problem of plugging with foreign matter in the fuel or in handling. Because of these small dimensions, a lower limit of 0.5 gallon per hour seems to be practical. This is not the most ideal equipment for handling high viscosity fuel. The nozzle is subject to changes in flow rates, spray angles and droplet sizes with changes in viscosity. This type of nozzle does not lend itself to operation at low pressure."

The speaker then brought to the attention of the group a listing of areas in which improvements or changes are desirable relative to pressure atomizing equipment, namely:

For the smaller sizes of pressure atomizing nozzles fuel viscosity should not be above 2.75 centistokes at 100 F.

Fuel should be stable and free of gum and sludge.

Pumps supplying fuel to nozzles as they are used today might possibly be redesigned to use less power. Only a very small fraction of the power supplied to the pump is used in atomizing fuel.

It may be possible to design burners to handle the larger droplets which would be produced by nozzles operating at lower than customary pressures.

Air atomizing equipment has proved itself to be free of some of the disadvantages of pressure atomizing equipment. It may be possible to reduce the cost of such equipment below what it is at the present time.

Other means of atomizing liquids may be discovered.

A completely new concept in fuel burning which may or may not in-

* Delavan Manufacturing Co.

clude atomization of the liquid may be possible."

John A. Bolt,* supplementing the other speakers, called attention to methods of removing and eliminating contaminants. External to the system he indicated the desirability of improved fuel-oil handling techniques, greater use of anti-rust agents in the fuel, closer attention to removal of water, and the need of better filters and screens in fuel lines, pumps, and nozzles. Internally he noted that continuing attention should be provided to produce a more stable fuel both in storage and in use. In storage the problems of color change, sediment formation, and soluble gums all arise. Stability can be improved by better blending of stable stocks giving specific treatments to the stocks and making use of additives. Not only is storage stability important, but also thermal stability as the oil moves into system zones of elevated temperature. As possible areas of future research, he called attention to the need of controlling fuel cleanliness by improved filters, water and dirt separators and repeated the need for developing better tests for determination of fuel stability.

Mixing of fuels and air – A. A. Putnam** started the discussion of this topic. Regardless of what other things are necessary concerning the combustion process, it is imperative that to burn a liquid fuel properly, good mixing must occur. For high energy outputs, intense mixing turbulence between the air and the fuel must be produced.

The first factor of importance in the mixing problem is the amount of momentum or "push" imparted to the fuel. If only an axially directed spray were used, as in the fuel jet of a diesel injector, the momentum effects would be quite simple to deduce. However, for conventional atomizing nozzles, where the spray exists in a solid – or hollow-cone pattern; there is little information concerning the implications of the momentum-mass flow relations of such patterns on the over-all flow of fuel, air, and products of combustion.

More important than imparting momentum to the air, however, is the atomizing function of the nozzle. The process of atomizing with conventional nozzles is extremely inefficient from an energy viewpoint. Thus, there is reason to believe that by modified design, atomization alone could be achieved at less expenditure of energy without sacrificing a desirable droplet-

... burner manufacturers can and will take advantage of closer oil specifications to improve burner design.

... continuing attention should be provided to produce a more stable fuel both in storage and use.

... a stable diffusion flame has a premixed flame as a leading edge; in a turbulent diffusion flame, this leading edge will distort and move about.

size distribution; the limit might be more in how much we can sacrifice the help of fuel momentum in our mixing process. In other words, we need energy to transport the fuel to desired locations.

Recent studies of the aspiration of air by fuel nozzles in completely open systems show that a fuel spray causes its own segregation by self aspirated air. As the air sweeps through the spray after being accelerated toward it, the smaller particles are aerodynamically swept up first, near the point of spray breakup, and then the larger ones are picked up further from the nozzle. Thus, with a hollow-cone spray, the smaller particles would be moved into the central region near the apex of the spray cone. Since small droplets, below about 5 or 10 microns, act as a premixed gas once a flame is started, in the region inside the cone near the apex, conditions should be optimum for burning easily as a premixed gas.

With a conventional blast tube in which the air outside the spray has an additional velocity component outward along the spray cone, there is a corresponding component of the gas flow inside the cone; thus, to preserve momentum, hot gases must often be brought back along the axis. Hot gases are also brought back or recirculated from downstream along the outside of the blast air. Depending on the various momenta involved and the amount of exceedingly small droplets inside the cone, one might have a wide range of mixtures of fuel, air, and hot gases. On the basis of some recent data, we would want a large amount of hot gases and fuel, and a small amount of air here. On the other hand, if a fuel-air ratio near stoichiometric could be attained in this critical region, it might be possible to propagate a turbulent flame against the oncoming air in the central cone, without any reverse flow of hot gases.

It should be noted that a stable diffusion flame has a premixed flame as a leading edge. In a turbulent diffusion flame, this leading edge will distort and move about to find acceptable conditions of fuel and oxygen, sufficiently hot to burn with the additional heat flux from the flame. There is even evidence of spontaneous spots of ignition in a turbulent diffusion flame as these three requirements are satisfied concurrently in a given region. However, again, the acceptable limits of these requirements are not entirely clear.

Throughout the previous discussion, we have emphasized the need for properly mixing products of combustion with vaporized fuel and fresh air. An interesting feature is that even if this use of products of combustion were not required for other purposes, recent studies have shown that higher rates of combustion per unit volume may be obtained by the proper recirculation of hot products. However, the important point to us, knowing that we need recirculation, is how to obtain, control, and predict it. Fortunately, from our point of view, the recent theoretical success in predicting results for a simple system implies that the problem cannot be too much more difficult for the flow and flame of the oil burner, within the limits of accuracy we need.

Walter B. Kirk* discussed the mixing of fuel gas and air and for the conference, he and an associate, E. J. Weber, had prepared a comprehensive paper. They noted that the mixing of fuel gas and air in domestic gas-burning equipment usually occurs in two stages. Hence, this subject of fuel-air mixing may be conveniently studied under the separate phases of primary aeration and secondary aeration. Up to the present, research has devoted considerably more attention to primary aeration than to secondary aeration. However, the complications of secondary aeration are now well appreciated, and at the same time, there is still a need for better understanding of primary aeration. So each stage in the aeration of fuel gas may well be a subject for further research.

"The primary air injected into the mixer tubes of drilled port burners is completely mixed with the fuel, for all practical purposes, in a travel of six to eight throat diameters. With a single port burner, having no burner head, it is questionable that complete mixing is ever obtained. However, the problems connected with primary aeration are not necessarily those of mixing, but rather of how to obtain all

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** Battelle Memorial Institute

* American Gas Assn. Laboratories

the primary air which may be desired and how to satisfactorily use the primary air once it is obtained.

Past research has attempted to derive relationships between primary air entrainment and burner design based on momentum exchange or on energy balances. Such relationships, being mainly empirical in nature, describe quite well the special conditions from which they were derived. However, they are not entirely satisfactory when applied to the many variations in design which can be concocted by engineers.

It is recognized that the momentum of the gas jet is only partly recovered in the momentum of the mixture of fuel gas and air leaving the burner ports. Friction with walls of the burner, back pressure of the flame, bouyancy of the mixture and the nature of the velocity distribution profile in the mixer tube are some of the factors which account for the unrecovered momentum. Actually, it is the complications introduced by these losses which, at present, make it difficult to predict with complete accuracy, the primary air injection of the atmospheric gas burner.

It is possible that further fundamental studies of primary air entrainment would lead to higher efficiencies for this process. At present, good burners recover almost 65 per cent of the gas jet momentum. So there is some room for improvement.

Today, 100-per-cent-primary-air, radiant-type burners, which were made possible through modern techniques and materials, are obtaining wide usage. If the efficiency of primary air entrainment could be increased, the radiation intensity of these burners would be much greater. Looking to the future, burners of this type with improved radiation characteristics could be combined with thermionic devices for the direct conversion of heat to electricity. Such a combination would be more simple and flexible than power burners which, at present, appear necessary for this application.

There are also indications that the use of flame retention devices may obtain more acceptance in domestic gas burner designs. Such devices improve flame stability in that they practically eliminate the problems of flame blow-off.

The second stage of aeration of flames of domestic gas burners is, for all practical purposes, limited to a simple diffusion process. Of course, the amount of secondary aeration is held to a minimum conducive to complete combustion in order to obtain a high thermal efficiency. The principal problem of secondary aeration, therefore, centers around completeness of combustion with a minimum of aeration.

The normal flow patterns in a combustion chamber include a downward flow of combustion products along the chamber walls. At some level in the chamber, this flow stream breaks from the walls and proceeds across the chamber to the flame. Unfortunately, these recirculating inert gases mix with the secondary air stream, and thereby, interfere with the combustion reaction. The flames will attempt to adapt themselves to this vitiated air supply by lengthening out to increase the area for diffusion. Most often, however, an excess of secondary air must be supplied to an appliance in order to obtain a reasonable oxygen concentration in the gases around the flame.

The effects of these recirculating combustion gases can, of course, be controlled by design. Tall, wide combustion chambers promote recirculation while short, narrow chambers tend to inhibit recirculation. Baffles above the flame reduce the effective height of a combustion chamber while baffles along the sides of the flame can serve to deflect the flow of inert gas away from the flame and the secondary air stream. Geometry of the burner, the amount of primary aeration and the magnitude of the fuel input rate are among other factors which modify the effects of recirculation. While there is some qualitative information available on these factors, considerable research work is needed to obtain the quantitative relationships."

"It seems reasonable to expect that continuing valuable information of the combustion mechanism will ultimately filter into the less spectacular combustion fields associated with heating."

Richard G. McCafferty* discussed the topic of stabilization of combustion. He considered this matter largely in terms of high energy release combustion, such as is met in turbo-jet, ram-jet and after-burner combustion systems associated with aeronautical propulsion. The problems in this field are more severe than those met in ordinary heating-system combustion, which is carried out at lower-energy-release rates. Nevertheless, similar problems exist in both systems, and some of the forward thinking carried out in propulsion systems may ultimately filter down to combustion problems relative to heating. He discussed the stability mechanism where bluff-body flame holders are used to position a flame and maintain stability and promote continuous combustion. A recirculation area behind the bluff-body contributes to the mixing problem and the stabilized flame. He considered the use of bluff bodies on flame stability and also mentioned that certain additives could contribute to the stability problem. It seems reasonable to expect that continuing valuable information of the combustion mechanism will ultimately filter into the less spectacular combustion fields associated with heating.

* National Aeronautics and Space Administration

Combustion in relation to air pollution — Wesley L. C. Hemeon* called attention to the problem of air pollution in industrial America. He mentioned that the various results of air pollution had already been a stimulant to the building of better combustion equipment. He called attention to various phases of air pollution, including the pollution from particulate matter and pollution of a chemical nature, including such items as partly burned hydrocarbons, sulphur dioxide, and the oxides of nitrogen. Some of these lead to smog conditions with accompanying physical discomforts. He mentioned that the trend away from solid to gaseous and liquid fuels had reduced, to a considerable extent, the amount of particulate matter in the air.

COMBUSTION IN THE FUTURE

Catalytic combustion — Dr. Walter Ross** discussed the topic of high-temperature catalytic surface combustion and for the conference, he, along with an associate, Howard L. Allen,** prepared a comprehensive paper. Sections of his paper follow, and at the end of this article, with their permission, the bibliography which the authors prepared covering the literature of catalytic and surface combustion is included. This summary should be of real interest to those wishing to carry out investigations in this field. Authors Ross and Allen stated that the title of their paper more properly should be, "High Temperature Catalytic or Surface Combustion." From the time of the first recognition of flameless incandescent combustion to the present day, there has been controversy as to what part, if any, catalysis plays in the phenomenon.

A catalytic agent is a substance

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** National U. S. Radiator Corp.

which by its mere presence alters the velocity of a reaction and which may be recovered unaltered in nature and amount at the end of the reaction. Catalytic processing has long been practiced in the chemical industry where it is used to produce billions of dollars worth of products each year such as gasoline, synthetic rubber, formaldehyde, ammonia, nitric acid and plastics.

In addition, catalytic oxidation has been used in combustion reactions in which the desired end result is heat generation. The most familiar catalysts used in such processes are members of the precious metals family such as platinum. This type of process is generally restricted to relatively low temperature applications such as the elimination of industrial fumes. For example, air streams containing hydrocarbons at concentrations below the flammable range must be heated to 1200 F or more to initiate and maintain oxidation, while the same streams are readily oxidized over a platinum catalyst in the range of 475-600 F.

The process that we visualize as an important "combustion of the future," however, is not this low temperature precious metal form of catalytic oxidation. Instead, it is high temperature flameless incandescent combustion, and herein lies the dilemma over the physical-chemical mechanism. A familiar case in point is the combustion on the surface of a refractory combustion chamber in a conventional oil-burning boiler or furnace. We all know that once equilibrium is reached, the combustion that occurs on these surfaces is intense, accelerated, flameless and incandescent. Is this surface combustion or is it catalytic combustion? For those of you who quickly and intuitively say that this is a clear cut case of surface combustion, I hasten to remind you of how remarkably well the chamber refractory fits the foregoing definition of a catalytic agent — to wit, a substance which by its mere presence alters the velocity of a reaction and is recovered unaltered in nature or amount at the end of the reaction.

One explanation of the phenomenon, and the one on which we will base the term "catalytic-surface combustion," is as follows:

As the temperature of a substance is raised, it exhibits increasing catalytic properties. With continued temperature elevation, more and more materials become more active in this sense until, at high incandescence, all materials (capable of withstanding such temperatures without spalling or changing state) exhibit roughly equal catalytic activity. This temperature-dependent behavior is based on electron emission from the incandescent body and consequent ionization of the impinging gas molecules, thus causing a reaction to take place between the mixture of fuel and a convenient oxidizer, usually air.

High temperature catalytic-surface combustion is not new—much of the classical as well as early practical work was done around the turn of the century. Only quite recently, however, has renewed interest and activity generated technological breakthroughs that offer promise of considerable commercial success. Nor is it unusual for an old theory to show new practical promise as a result of either new technology or the discovery and synthesis of new materials. The current and promising work underway in Peltier heating and cooling and in thermionic conversion attest to this fact.

The most notable theoretical contributions to this field were made by two Englishmen in the early 1900's, Professor W. A. Bone of Manchester University, who developed a theory of flameless incandescent surface combustion, and H. H. Gray, who critically reviewed Bone's theory and followed it with one of his own. More recently, two Russians, V. L. Korneev and D. M. Khamalyan proposed a third new theory.

In 1914, Gray critically reviewed Bone's theory. In so doing, he denied the existence or even the necessity of any catalytic activity at high temperatures and then proposed his own explanation of the phenomenon which has become known as the Detonation Theory.

In his paper, Gray objected strongly to a step taken by Bone when he discussed catalytic combustion at low temperatures and then unhesitatingly bridged the gap by saying that these results are applicable to high temperature phenomena. At low temperatures where the natural tendency for combustion of gaseous mixtures is not too great, the effect of the presence of a catalyst can be readily proven by experimental means. It is questionable, however, whether the same reasoning can be applied to the reaction at high temperatures without proving that the natural combustibility of the "explosive" mixture is overcome and replaced by catalysis.

In his explanation of flamelessness, Gray cited several examples of flames where the actual size of the flame varies. These are, in order of flame size: (1) a luminous coal gas flame from a bunsen burner; (2) an aerated bunsen flame; (3) an over-aerated "roaring" bunsen flame; (4) a Meker flame; and (5) an oxy coal-gas flame. From this, he noted that the size of the flame is reduced in proportion to its aeration. A straggling flame, therefore, could be considered as one which is reaching out for oxygen and which is not properly mixed or "tuned up." From this, he deduced that the aeration is a potent factor in producing flamelessness and can be explained without the intervention of catalysis.

The basis for Gray's Detonation Theory to explain flameless incandescent surface combustion can be outlined as follows:

> Detonation is a very rapid form of combustion which contributes in part to flamelessness.
>
> It is a propagation of chemical changes in a gaseous medium which is independent of any solid surface being present.
>
> It is set up and propagated by the heat generated by any incandescent surface.
>
> The chemical change is propagated in a thin layer known as a wave front.
>
> The "flamelessness" results from an abundant aeration that is necessary for detonation to occur.

The Detonation Theory as applied to surface combustion is one in which the normally dangerous explosion wave is prevented by the baffling of the granular or porous refractory material and the rapid flow of the explosive mixture in a direction opposite the potential direction of the explosion wave.

In 1948, the Russian scientists, Korneev and Khamalyan, published a paper in which they reported the results of their investigation of surface combustion. They discovered that the time-space heat intensity of hydrocarbon gases is increased when the diameter of the burner is decreased. This is associated with an increasing surface area of the flame cone per unit volume.

Specifically for a C_6H_6-air mixture they explained that when the burner was of 50 mm diam, the flame cone measured 84 mm in length and the heat intensity was 88.5×10^6 kcal/cu m-hr. When a wire net of 2 x 2 mm mesh size was introduced, the flame was split into a number of microflames. The length of the cones was reduced to 6-8 mm and the heat intensity increase of 450 per cent was brought about by the approximate 90 per cent decrease in flame-cone length.

From these enlightening results, Korneev and Khamalyan concluded that the so-called flameless combustion in layers of refractory materials

is nothing other than microflame burning. The increased heat intensity results from the flame splitting into a multitude of small cones and not from a catalytic effect of the ceramic material.

Fuel Cells – Dr. Everett Gorin* was the final speaker at the conference. He discussed the problem of fuel cells. By definition, a fuel cell is a primary-electrode chemical device which uses the oxidation of a fuel to convert directly a portion of the heat of combustion into electrical energy. True fuel cells operate continuously with a steady and constant output of electrical energy with a supply of fuel to the negative electrode and with oxidant supply to the positive electrode. He mentioned the earlier success which had been attained with hydrogen-oxygen cells, but commented on the recent success which of a CO-CO_2 fuel mixture operating with air employing two porous electrodes in gas pressure balance on either side of an electrolyte matrix. Although the fuel cell as a direct source of electrical energy, is still in experimental or pilot stage, it nevertheless holds promise of becoming a potentially significant source of future power.

Conference summarization was presented by L. N. Hunter* and a recommendation was made from the floor by Herbert T. Gilkey** who:

MOVED: Those attending the Combustion Conference recommend to the Research and Technical Committee that the proceedings of the Conference be reviewed by appropriate Society committees with a view to:

a. Establishing research on some or all of the problems outlined at the Conference, and to

b. Aid in establishing or revising standards on fuel so that development of improved fuel burners will be encouraged.

This motion was seconded and unanimously approved.

* Consolidation Coal Co.

* National-U. S. Radiator Corp.
** National Warm Air Heating and Air Conditioning Association

BIBLIOGRAPHY

1. Bement, A., "Flameless Combustion", *Power,* Vol. 37, p. 27, 1913
2. Bone, W. A., "Coal and Its Scientific Uses", *London Logmans,* 1918
3. Bone, W. A., "Gas Combustion at Hot Surfaces", *Engineering News,* Vol. 67, pp 96-97, 1912
4. Bone, W. A., and Kirke, P. S. G., "Recent Developments in Surface Combustion Boilers", Journal of Society of Chemical Industry, Vol. 38, pp 228T-234T, 1919
5. Bone, W. A., "Surface Combustion", *Howard Lectures, Proceedings Royal Society of Arts,* July 31, 1914
6. Bone, W. A., "Surface Combustion and Its Industrial Applications", *Journal of Gas Lighting, Water Supply, etc.* Vol. 118, pp 432-434, May, 1912
7. Bradford, J. L. and Corwin, C. D., "Some Recent Experiments in Surface Combustion", *Power,* Vol. 42, pp 787-788, 855-859, 1915
8. Campbell, A. J., "Surface Combustion", *Transactions Ceramic Society,* Vol. 12, Part I, pp 18-32, 1913
9. Campbell, D. A., "Characteristics of Basic Gas Combustion Equipment", *Steel,* Vol. 121, No. 12, pp 78-79, 103-108, 1947
10. Eickhoff, Dr. C. Fr. R., "Higher Heat Output From Same Quantity of Fuel", *Haustechnische Rundschau,* Berlin, Issue 4, page 76 April 1956 (Also in Issue 7, page 147, July, 1957) In German
11. Gray, H. H. "A Critical Review of Flameless Incandescent Surface Combustion", *Journal of Gas Lighting, Water Supply, Etc.,* Vol. 126, pp 786-789, June, 1914
12. "Handbook of Chemistry and Physics", 34th edition, Cleveland, Ohio, Chemical Rubber Publishing Company, 1952-3
13. Heidtkamp, G., "Basic Theoretical Analysis of Gas-Fired Schwank Radiants"
14. Houdry, E. F., "Piston Engines Operated by Catalytic Oxidation of Fuel", British Patent 690805, Application Date March 17, 1949
15. James, H., "Pressure Limits of Combustion", *French Academy of Science Technical Paper,* pp 2238-2241, April 1946, (in French)
16. Jones, W. Norton, Jr., "Inorganic Chemistry", York, Pennsylvania, Blakiston Company, 1949
17. Kershaw, John B. C., "Flameless or Surface Combustion", *Metallurgical and Chemical Engineering,* Vol. 9, pp 628-630, 1911
18. Khudyakov, G. N., and Puskin, V. S., "Flameless Burning". *Bull. Acad. Sci. U.R.S.S., Classe Sci, Tech.,* pp 545-553, 1949. (in Russian)
19. Korneev, V. L., and Khamalyan, D. M., "Flameless Combustion of Gases". *Prom. Energetika,* Vol. 6, No. 4, cf. C. A. 42, 7505F, pp 7-8, 1949
20. Korneev, V. L., and Khamalyan, D. M., "Microflame Burning" *Prom. Energetika,* Vol. 5, No. 1, pp 3-7, 1948
21. Latta, Nisbet, "Three Principal Difficulties Presented in the Use of the Surface Combustion Principle for the Gas Firing of Boilers", *American Gas Light Journal,* Vol. 105, No. 5, pp 225-229, October 9, 1916
22. Lewis, B., Peace, R. N., and Taylor, H. W., "Combustion Processes", Princeton University Press, 1956
23. Lewis, B. and von Elbe, G., "Combustion, Flames and Explosions of Gases", Academic Press, New York, 1951
24. Lucke, C .E., "Design of Surface Combustion Appliances", *Journal of Industrial and Engineering Chemistry,* Vol. 5, pp 801-824, October, 1913
25. Meunier, J., "Combustion of Gas by Incandescence and Some Instances of Gaseous Cohesion", *Bull. Soc. Chem.* pp 3-4, 5 & 9, May 20, 1908
26. Meunier, J., "Combustion of Gas Without Flame and the Condition of Illumination by Incandescence". *Compt. Rend.* 148, 292-4
27. Meunier, J., "Combustion Without Flame and Its Application to Lighting by Incandescent Mantles", *Compt. Rend.* 146, 864. April 21, 1908
28. Meunier, J., "Combustion Without Flames and the Burning of a Gas at the End of a Metallic Tube", *Compt. Rend.* 146, 539, March 9, 1908
29. "Principles and Application Criteria of Catalytic Heating" American Thermocatalytic Corporation, 1957
30. Ravich, M. B., "Surface Combustion, Its Theoretical Basis, and Prospects of Application in Connection with the Utilization of Fuel Gas", *Bull. Acad. Sci. U.R.S.S Classe Sci, Tech,* pp 833-846, 1946 (in Russian)
31. Read, H. L., "Some Results of Recent Work with Surface Combustion," *Power,* Vol. 45, pp 225-226, 1917
32. Reserk. Marc. "Atmospheric Gas-Fired Infrared Heaters for Processing Applications" ASME Technical Paper No. 58-A-210, 1958
33. Sanderson, L., "The Infrared Gas Burner". *Metallurgia,* Vol. 35, pp 187-189, 239-240, 1947
34. Schramm, E., and Cam, J. R., "A Test of a Surface Combustion Furnace" *Journal Industrial and Engineering Chemistry,* Vol. 5, No. 3, pp 173-184, November 1955
36. Thomas, J. D., "Surface Combustion for Domestic Uses", *Gas Age,* Vol. 37, pp 669-670, 1916
37. Weiss, G., "Thermocatalytic Reactors and Their Use in Gas Heating Appliances", *A.G.A. Research and Utilization Conference,* May 6, 1959

GENERAL ITEMS

38."CTS" Testing—New Use for Infrared Heating of Rapid Station Platform", *Passenger Transport*, Vol. 15, No. 35, December 20, 1957
39. Foulds, C. H., "Infrared Heat for Tomorrow's Bus Garage", *Mass Transportation*. November, 1957
40. Foulds, C. H., "Infrared System Efficient in High-Bay Buildings", *Foundry,* January, 1958
41. Foulds, C. H., "Radiant Heating for the Modern Plant", *Better Building Maintenance*, December 1957
42. "Foreign Unit Fires New Interest in Infrared Heat", *Chemical Week,* February 8, 1959
43. Garve, T. W., "Accelerated Radiated Heat Drier", *American Ceramic Society Bulletin,* No. 27, Structural Clay Products Div., pp 299-300, 1948
44. "Gas-Generated Infrared Heat", *Plant Engineering,* December, 1957
45. Gavrilenko, V. S., "Flameless Gas Heating in Industrial Plants", *Prom. Enegetika* 5, No. 5, pp 9-11, 1958
46. "How to Place Heat Where it is Needed", *Railway Track and Structures,* February 1958
47. "Infrared Heating Saves 55% in High-Bay Plant", *New York Industrial World,* October, 1957
48. "Infrared Heating Saves 55% in New Jersey Plant", *Gas Age*, February 6, 1958
49. Jennings, A. C., "Some Notes on the Gas Industry", *The Gas World,* 127 Vol. 20, No. 11, *Industrial Gas Supplement,* pp 137-142, November 15, 1957
50. "Low Cost Winter Comfort". *Modern Castings,* December, 1957
51. Meigel, H., "Fume Elimination May Be Only Half the Story", *Industry and Power*, December, 1955
52. Minchin, L. T., "The Burning of Gaseous Fuels, III. Recent Developments", *Coke and Smokeless—Fuel Age,* cf. C. A. 41, 5703F., pp 247-249, 1946
53. "New Heating System Warms Batavia Downs Seating Deck", *The Horseman and Fair World*, October 30, 1957
54. "Plant Design for Efficient Clay Pipe Production", *Ceramic Age*, December, 1957
55. Unterweiser, P. M., "Luminous Wall Firing: Low Cost Idea in Rapid Heating", *The Iron Age*, December 4, 1958

FUEL CELLS

56. Bacon, F. T., *Bama Journal,* Vol. 61, 1954, pp 6-12
57. Ketelaar, J. A. A, *Die Ingenieur,* Vol. 66, August 20, 1954, pp E88-91
58. Broers, G. H. J., PhD Thesis, University of Amsterdam, The Netherlands, 1958
59. Zielke, G. H. J. and Gorin, E., *Industrial and Engineering Chemistry,* Vol. 47, 1955, pp 820-825
60. Davis, W. Kenneth, Roddis, Louis H. Jr., and Goodman, Clark, *Nucleonics,* Vol. 15, 1957, pp 90-93
61. Kasten, Paul R. and Claiborne, H. C., *Nucleonics*, Vol. 14, 1956, p 88
62. Bacon, F. T. and Forrest, J. S., "High-Pressure Hydrogen-Oxygen Fuel Cell", *Engineer*, Vol. 202, July 20, 1956, pp 93-94 (from Fifth World Power Conference Paper No. 119k/4, Vienna, Austria, 1956)
63. Rideal, E. K., *Zeitschrift fur Electrochemie,* Vol. 60, 1958
64. Gorin, E. and Recht, H. L., "Fuel Cells". *Mechanical Engineering,* March, 1959, Vol. 81, pp 63-65

ASHRAE RESEARCH ON PULSATIONS IN RESIDENTIAL HEATING EQUIPMENT

65. Putnam, A. A. and Dennis, W. R., "Pulsations in Residential Heating Equipment", ASHAE *Transactions,* Vol. 63, 1957, pp 153-171
66. Speich, C. G., Dennis, W. R., and Putnam, A. A., "Acoustic Coupling of Residential Furnaces with Their Surroundings", ASHAE *Transactions,* Vol 63, 1957, pp 413-427
67. Putnam, A. A., "Pulsations in Residential Gas Furnaces with Multiple-Port Burners", ASHAE *Transactions,* Vol. 64, 1958, pp 377-401
68. Speich, C. F. and Putnam, A. A., "Pulsations in Single-Port Gas-Fired Residential Heating Equipment", *Heating Piping & Air Conditioning,* November, 1958, Vol. 30, pp 139-147
69. Putnam, A. A. and Speich, C. F., "Suppression of Oscillations in Gas-Fired Residential Heating Equipment", *ASHRAE Journal,* August 1959, Vol. 1, pp 41-45.

Psychrometric charts

past and present

Psychrometric charts are probably the most widely used graphical devices of the refrigerating and air conditioning industry. Their principal purpose is to show the relation between six major properties of moist air: dry bulb temperature, wet bulb temperature, moisture content (humidity ratio), relative humidity, enthalpy, and specific volume; and to provide graphical solutions to processes where air changes from one condition to another. The possible arrangements of coordinates and parameters are almost unlimited, with the result that psychrometric charts have appeared over the years in a wide variety of forms. An important factor has been the problem of presenting a network of so many variables in a form that would be easily and accurately readable.

Discussed herein are several of the more popular types of psychrometric charts in the light of their present usage and historical background. Thermodynamic principles are included only as they affect the graphical form, since this phase has been liberally treated by many others. Similarly, for the technique of measuring true wet bulb temperatures, the reader is referred to the profuse literature[1] on that subject.

Even a casual review of psychrometric charts reveals a divergence of opinion that has long existed between thermodynamicists who develop the basic psychrometric data from which charts are constructed and engineers who use such charts in their day-to-day work. So far, no single chart has met the perfection desired on the one hand in combination with ease of use and practical accuracy desired on the other. It is of more than passing interest to note that these divergent viewpoints are exemplified by the charts in the most recent ASHAE Guide[2] and ASRE Data Book.[3]

D. D. WILE
Member ASHRAE

Pioneer chart makers—A most significant milestone in the progress of air conditioning occurred in 1911 when Willis Carrier[4] published a rational relation between wet bulb temperature and the thermodynamic properties of moist air. Carrier made his calculations in 1903, only two years after his graduation from Cornell University, and began his confirming tests in 1904. He, however, was not the first to suspect a thermodynamic basis for the wet bulb readings. He credits Apjohn[5] with having propounded the same theory in 1836, although Apjohn, using a wet bulb thermometer in still air, was unable to prove his assumptions. Nor was Carrier the first to publish a psychrometric chart. Grosvenor,[6] in 1908, published an elaborate chart, which, however, did not establish the wet bulb lines.

Carrier's historic paper presented proof of his assumptions and he included a practical psychrometric chart along with his rather complete psychrometric data. He thus laid a sound foundation for the many phases of air conditioning even as practiced today. It is interesting to note that the recorded discussions of Carrier's paper heralded a controversy that continues to this day.

Sigma heat vs. enthalpy controversy—Fig. 1 is a schematic diagram of Carrier's 1911 chart. The wet bulb line is a path of "adiabatic saturation" or of "adiabatic wet bulb temperature." The adiabatic saturation process is so vital to psychrometry that it will be reviewed briefly here. In Fig. 2 air passes through a saturating device insulated to prevent flow of heat from the outside. As the air picks up moisture, there is an interchange of sensible and latent heat whereby the dry bulb temperature is reduced. Wet bulb thermometers placed along the path of the air will show substantially the same readings even though the air enters dry and leaves saturated. The water in Fig. 2 will assume the wet bulb temperature. If the adiabatic process is continuous, water must be added to the saturator at the wet bulb temperature, t'.

It is significant that while the sensible heat decrease of the air exactly equals its increase of latent heat, in this adiabatic process, there will be a small change of enthalpy. Enthalpy is measured from an arbitrary base, usually 32

Any review of psychrometric charts must naturally lead to some conclusions and possibly some preferences regarding their general arrangement and structure. This comprehensive discussion of the history of the psychrometric chart is thus the author's considered expression of opinion regarding some basic and some derived factors.

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[1] Exponent numerals refer to references at the end of this article.

D. D. Wile is Vice President, Recold Corporation, and First Vice President, ASHRAE. This paper is an amplification of a similar discussion by the author at a Symposium at Marquette University in February, this year.

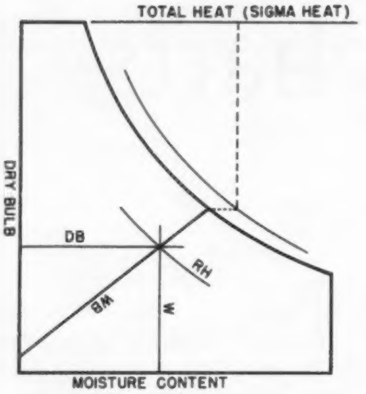

Fig. 1 Psychrometric chart of W. H. Carrier

This is a simplified diagram of Carrier's original psychrometric chart, published in 1911. Although not the first published chart, it was based on rational principles and marked the start of modern air conditioning science. While basically sound, this chart elicited criticism from the thermodynamicist by use of the term "total heat" to define the wet bulb line. Carrier later adopted the term "Sigma Heat" (see text).

CONDITION OF AIR	DRY	MOIST	SATURATED
MOISTURE CONTENT*	0	W	W_s
DRY BULB TEMP.	t_0	t	t_s
WET BULB TEMP.	t'	t'	t'
ENTHALPY OF MOISTURE*	0	$W(t'-32)$	$W_s(t'-32)$
ENTHALPY OF AIR*	h_a	$h_a+W(t'-32)$	$h_a+W_s(t'-32)$

* PER POUND DRY AIR

Fig. 2 Adiabatic saturation process

Not quite as simple as first appears. Dry air entering the saturator from the left leaves saturated at the right. Its wet bulb temperature remains substantially constant. Latent heat increase exactly equals sensible heat decrease, but there will be a small gain of enthalpy due to the enthalpy of the added moisture.

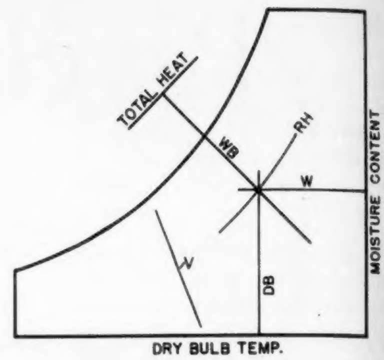

Fig. 3 Psychrometric chart of F. O. Urban

Psychrometric charts became more practical and easier to use in 1934 with this arrangement by F. O. Urban. He: (1) Replaced the auxiliary enthalpy curve and vertical scale by a simple diagonal scale; (2) replaced the confusing "Sigma Heat" with enthalpy at saturation (unfortunately called "total heat"); (3) replaced auxiliary curves and scales for volume by placing widely spaced volume lines directly on the chart.

F for water or water vapor. Thus the enthalpy of the air, in an adiabatic saturating process, increases slightly with increasing moisture content due to the enthalpy of the water above the arbitrary 32 F base.

The equation of a wet bulb line, in relation to moisture content (W) and enthalpy (H), is

$$H = H_a + W f' \qquad (1)$$

where H_a is the enthalpy of dry air at wet bulb temperature t' and f' is the enthalpy of water at the wet bulb temperature, (t'-32) for all practical purposes.

In the comfort air conditioning range, the wet bulb lines, as defined by Equation 1, incline so slightly from the enthalpy lines as to cause difficult reading when both wet bulb lines and enthalpy lines are shown. Numerous expedients, intended to improve this situation, have evolved over the years.

In Carrier's 1911 chart, as shown in Fig. 1, the "total heat" (the word enthalpy had not yet come into use) scale at the left is actually the enthalpy of dry air at the wet bulb temperature and differed from total heat by the term Wf'. Use of "total heat" in this connection was unfortunate and drew considerable criticism even though Carrier's text carefully explained the adiabatic saturation process. Carrier later[7] introduced "sigma heat" in place of the erroneous "total heat," and that term was widely used on psychrometric charts until recent years. Deviation of sigma heat from enthalpy, as expressed by the term Wf' in Equation 1, seldom caused errors in computed load of more than 1.5% and was frequently ignored. More often, the significance of sigma heat was not clearly understood. Arrangement of the sigma heat scale contributed to the confusion because its readings were projected from the saturation curve while it actually represented the enthalpy corresponding to the wet bulb temperature at zero moisture content.

Enthalpy at saturation – A significant contribution to chart construction was made by F. O. Urban,[1] of the General Electric Company, with a chart copyrighted in 1934 and shown diagrammatically in Fig. 3. Urban introduced the diagonal scale of enthalpy rather than projecting to an auxiliary curve as in Fig. 1. Then, instead of the sigma heat function, he used "enthalpy at saturation" although he called it "total heat."

Actual enthalpy, along the wet bulb line, deviates from enthalpy at saturation by the term $(W_s - W)f'$ which follows from Equation 1 by writing

$$H_s = H_a + W_s f' \qquad (2)$$

and

$$H = H_s - (W_s - W)f' \qquad (3)$$

where

H, W = enthalpy* and moisture content* at any point along the wet bulb line t'.

H_a, H_s = enthalpy* of dry and saturated air at t'.

W_s = moistures content* of air saturated at t'.

f' = enthalpy of water at t'.

* per pound of dry air

The deviation term $(W_s - W)f'$ in Equation 3 is somewhat more complex than the deviation from sigma heat (Wf') in Equation 1, but in comfort air conditioning is generally of smaller magnitude.

The relation between enthalpy at saturation and sigma heat is shown in Fig. 4, where it should be noted that deviation of the wet bulb line from enthalpy at saturation is small near the saturation curve; while its deviation from sigma heat is small at low humidity. For comfort air conditioning processes, the deviation of enthalpy at saturation is usually ignored without significant error in the heat load calculation. This deviation cannot, however, be ignored where precise load calculations are essential, such as in laboratory work.

The constant volume lines, shown diagrammatically in Fig. 3, were also original with Urban. Since volume changes are small over the range of the chart, the lines can be widely spaced, provide a convenient index of volume and eliminate the complex scale arrangements that appeared on previous charts.

Enthalpy deviation contours – In 1946 Palmatier and Wile[8] intro-

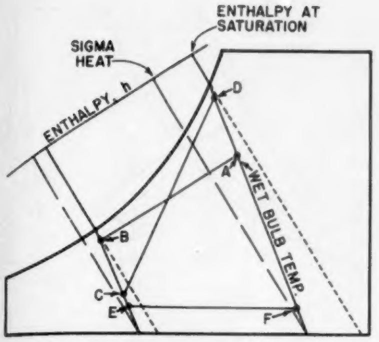

Fig. 4 Relation between enthalpy at saturation and sigma heat

Here exaggerated. For air conditioning and refrigerating processes, as represented by lines A-B and C-D, the deviation from true enthalpy is less when using an "enthalpy at saturation" scale. For processes at extremely low humidities, represented by line E-F, the deviation would be less when using a "Sigma Function" scale. On actual charts, the enthalpy lines are so nearly parallel to the wet bulb lines that some expedient must be used to avoid confusion.

duced a chart, shown schematically in Fig. 5, that used Urban's enthalpy at saturation concept, but added "enthalpy deviation" contours. These show at a glance the deviation of enthalpy at saturation from the true enthalpy at any point along a wet bulb line, permitting precise determination of enthalpy without using both wet bulb and enthalpy lines. Since the deviations are relatively small, the contours can be widely spaced and add little complication to the chart structure. A chart of this type has been used in the ASRE Data Book since 1947.

Reduced enthalpy – In an effort to avoid the confusion between wet bulb and enthalpy lines, Goff[9] prepared a chart in 1945 having "reduced enthalpy" lines (H−1000W), as shown in Fig. 6. This device, for rotating the enthalpy lines, required additional calculations and, furthermore, the position of the reduced enthalpy lines became nearly parallel to the dry bulb lines. This chart was supplied with the ASHVE Guide through 1950. Following that time the Guide chart, as proposed by Nottage,[10] has presented both wet bulb and enthalpy lines as shown in Fig. 7. Confusion of these nearly parallel lines is only partly avoided by the use of solid black lines for one and dashed-red lines for the other.

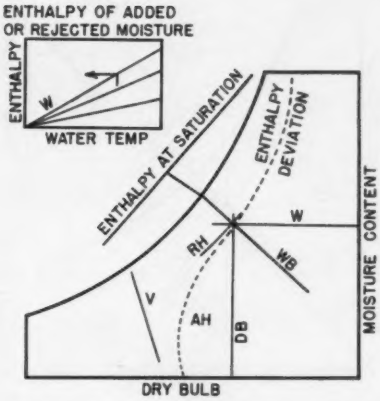

Fig. 5 Psychrometric chart of E. P. Palmatier and D. D. Wile, using the enthalpy deviation contours

The recent ASRE Data Book charts use "Enthalpy Deviation contours" for easy determination of the small enthalpy deviation along the wet bulb lines. The diagram at upper left gives the enthalpy of water, added or rejected from the air.

Enthalpy of the added or rejected moisture – When moisture, at the wet bulb temperature, is added to or rejected from air, it carries a quantity of heat that is commonly ignored without involving significant errors in comfort air conditioning load calculations. However, the error from this source frequently exceeds the enthalpy deviations previously discussed and should not be neglected where precise results are desired. In addition, this error may become significant where moisture is rejected in the form of ice or the added water is heated or cooled.

While the enthalpy of the added or rejected moisture is calculated easily, it can be conveniently determined from a simple diagram such as shown in the upper left hand corner of Fig. 5 (the ASRE chart). The actual chart represented by Fig. 5 had a similar diagram for enthalpy of ice at various temperatures.

A different approach to the enthalpy of added or rejected moisture was published by Keppler[11] in 1934 and has appeared in modified form on the ASHAE charts since 1945. A protractor, as shown in Fig. 7, determines, by the slope of the process line, the heat added or rejected per lb of water. This device offers some convenience where water is the only source of heat, such as cooling with chilled water or humidifying with

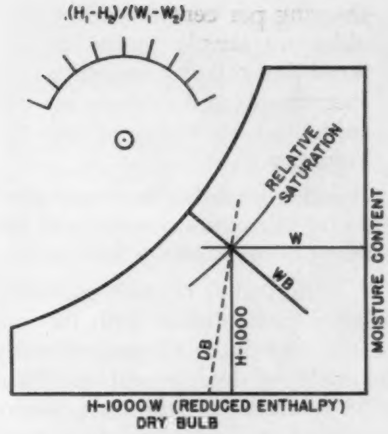

Fig. 6 ASHVE Guide chart of 1945

Here "Reduced Enthalpy" was used as a device to avoid confusion between wet bulb and enthalpy lines. The "reduced enthalpy" lines however involved added calculations and also became nearly parallel with the dry bulb lines. This chart used "Relative Saturation" (related to moisture content) rather than the familiar "Relative Humidity". The small protractor gives the enthalpy of added or rejected water.

hot water or steam. When heat is added or removed by other sources in addition to the water, the method appears to offer little advantage over reading enthalpy changes from the conventional enthalpy scale.

Relative humidity vs. relative saturation – During recent years, there have been efforts to replace or supplement the familiar "relative humidity," based upon vapor pressure, with the ratio of the moisture in one lb of dry air to its moisture content at saturation. This latter ratio has assumed various names, including "degree of saturation," "per cent saturation" and "percentage humidity," but will be called "relative saturation" in this paper.

The principal argument for relative saturation states that it is based upon actual quantities rather than upon vapor pressure which is, in itself, a derived quantity. The arguments for relative humidity as presented in a previous paper[8] are:

Per cent saturation loses its significance above 212 F where moisture content per lb of dry air at saturation becomes infinity.

A chart which shows relative humidity also provides per cent saturation by the division of two moisture contents, while a chart

showing per cent saturation provides no simple means of determining relative humidity.

Instruments and controls are still calibrated in terms of relative humidity.

Relative humidity is an accepted factor of human comfort and the effect of moist air on materials.

Historically, relative humidity was well established with the use of the wet bulb thermometer by Baume[12] (of hydrometer fame) in 1758 to measure "the evaporative power of air," which is most probably related to vapor pressure. In meteorology the dew point instrument has long been used to measure the humidity of air. Dew point is related to vapor pressure and thus to relative humidity.

Relative saturation came into prominence with the Goff chart of 1945 which replaced the familiar relative humidity lines with lines of "per cent saturation," based on relative moisture content. Omission of the relative humidity lines led to such confusion, and complaints from users, that the Guide chart of 1951, continuing to the present, has lines for both relative humidity and relative saturation, as shown in Fig. 7.

Thus it appears that common usage demands the relative humidity lines and practical considerations should eliminate the complication of the dual lines, especially since relative saturation can be calculated so easily on the infrequent occasions when it may be required.

Dry bulb vs. enthalpy coordinates – It has been conventional practice to construct psychrometric charts with major coordinates of dry bulb and moisture content. After laying out the rectangular grid of dry bulb and moisture content lines, the wet bulb lines are then located on these coordinates, the wet bulb lines being curved slightly and the enthalpy scale being of non-uniform spacing. Constructed in such a manner, the chart will give accurate values for the properties of air at any given state point; however, a straight line drawn between two state points will not indicate precisely the state of mixtures between the two terminal points. For processes in the comfort air conditioning range, the error from this source is generally negligible for practical purposes.

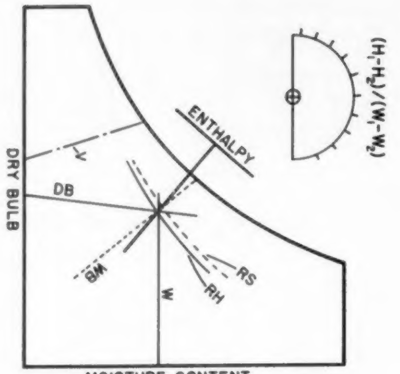

Fig. 7 ASHVE Guide chart from 1951 to the present

This displays both the enthalpy and wet bulb lines. The use of two colors only partly avoids the confusion of these nearly parallel lines. Both relative saturation and relative humidity are also shown.

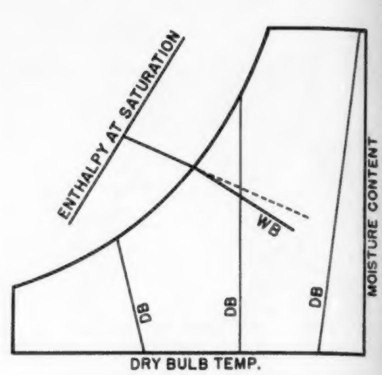

Fig. 8 Divergence of dry bulb lines when coordinates are enthalpy and moisture content

When basic coordinates are Enthalpy and Moisture Content, the dry bulb lines will diverge slightly (shown greatly exaggerated here), but the chart will avoid slight errors that exist when dry bulb temperature is used as one of the coordinates. The enthalpy line (shown dotted) need not appear on the finished chart.

Mollier[13, 14] (of steam chart fame) in 1923 proposed coordinates of enthalpy and moisture content, with dry bulb temperature as a parameter. If the enthalpy coordinate is at an oblique angle, the chart will have the conventional appearance, with the exception that the dry bulb lines, instead of being parallel, will diverge slightly as shown exaggerated in Fig. 8. For a chart covering a fairly wide temperature range, such as the current ASHRAE chart with a range of 0 to 125 F, the inclination of the dry bulb lines is hardly detectable to the eye except when comparing the right hand edge of the chart with the edge of the paper on which it is printed. It might be somewhat more desirable to select the angle of the oblique enthalpy lines to bring the right hand edge of the chart perpendicular to the moisture content lines and thus parallel to the edge of the paper.

It should be noted that a chart constructed with enthalpy as one of the coordinates need not retain the enthalpy lines within the body of the chart where they are so nearly parallel to the wet bulb lines. Parallel enthalpy lines, however, extended from the saturation curve to an oblique, but uniformly spaced, enthalpy scale will define enthalpy at saturation.

This selection of enthalpy rather than dry bulb temperature as the second coordinate in combination with moisture content has been the subject of some heated discussion, but it appears that advantage is all on the side of enthalpy. Basic accuracy is achieved without adding complications or changing the general arrangement of the chart. Actual construction of the chart should be no more difficult and possibly less so with the enthalpy-moisture content coordinates.

Variable elevation charts – With rare exceptions, psychrometric charts in general use are for standard barometric pressure at sea level and this includes those charts supplied with the ASRE Data Book[2] and the ASHAE Guide.[3] The ASRE chart includes a table of corrections along with formulas that can be (but rarely are) used to determine the properties of moist air at various elevations. The ASHAE Guide dismisses the subject of psychrometry at other than sea level elevation by the statement, "For many design problems, the use of the standard pressure chart will not incur any undue error up to about 2,000 ft above sea level."

Due to the lack of convenient psychrometric charts for higher elevations, frequent practice, even at elevations of 5,000 ft or more, is to solve air conditioning problems on sea level charts and then apply some arbitrary multiplier to the calculated load. Such arbitrary

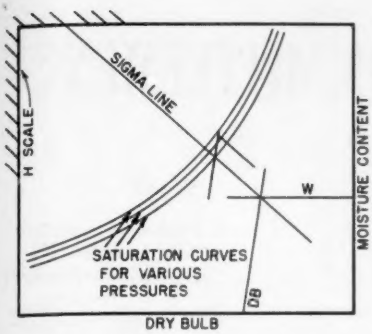

Fig. 9 Variable elevation chart of W. Goodman (1939)

Such charts have multiple saturation curves. Wet bulb lines are replaced by Sigma function lines that take on the wet bulb temperature indicated by the intersection of dry bulb lines with the saturation curve for any particular elevation.

factors are likewise applied frequently to the performance of air conditioning equipment when the manufacturer does not supply performance data for the higher elevations.

A psychrometric chart can be constructed for variable elevation by including multiple saturation curves as shown in Fig. 9. The wet bulb lines, as such, must be replaced by adiabatic saturation (sigma function) lines as defined in Equation 1. These lines then take on the wet bulb temperature indicated by the intersection of dry bulb temperature lines with the saturation curve for any particular elevation. Enthalpy lines may also be shown on a variable elevation chart, but enthalpy at saturation along with relative humidity and relative saturation are not applicable due to the change of moisture content of saturated air at various elevations. Numerous variable elevation charts appear in the literature; noteworthy among these is the Goodman[15] chart published in 1939, the Bureau of Mines[16] chart of 1947, the Sharpe-Moore[17] chart of 1950 and the Jennings-Torloni[18] charts published in 1954. The Bureau of Mines chart includes ratios, related to the barometric pressure, for relative humidity and specific volume.

The variable elevation psychrometric chart serves a real need, but is inconvenient to use, requiring application of wet bulb values to the adiabatic saturation lines, and these may be integral values for only one elevation. At all other

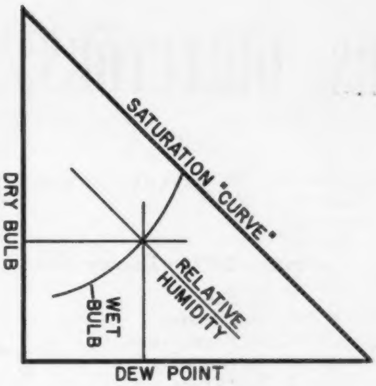

Fig. 10 Psychrometric chart of C. A. Bulkley, using modified logarithmic scales

This offered more uniform accuracy over a wide range of temperature and humidity. It was unsuited for graphic presentation of air treating problems. This chart appeared in ASHVE Guide from 1926 through 1941.

elevations the wet bulb lines take on fractional values. The absence of relative humidity and volume lines is another source of inconvenience. A more practical solution appears to be several charts covering the desired elevation range with increments as large as consistent with desired accuracy.

If we accept the 2,000 ft tolerance suggested by the ASHAE Guide, then a conventional type chart for standard sea level pressure could be used for elevations up to 2,000 ft and a second chart for 4,000 ft elevation could be used in the range of 2,000 to 6,000 ft. Maximum errors, at 2,000 and 6,000 ft, for load calculation between 80 F and 67 F wet bulb temperatures would be 6.3%. These charts would avoid the complication of the variable elevation feature. The errors resulting from the use of charts over such a wide range of elevations would be within the available knowledge of comfort conditions at various pressures. Furthermore, it should be noted that actual barometric pressure varies considerably from time to time at any particular location, such variations being ignored generally in the practical performance of refrigerating and air conditioning systems.

Other chart forms – The general form of the psychrometric chart is established by the arrangement of any two of the major properties of moist air as coordinates, since all other properties then fall as parameters on these coordinates. The arrangement presently in most common use is that shown in Figs. 5 and 9 where moisture contents (humidity ratio) appear as horizontal lines extending from a vertical scale and dry bulb temperatures appear as vertical or nearly vertical lines extending from a horizontal scale.

Of the many other possible arrangements, the charts of Hill and Bulkley deserve mention because these quite similar charts were both in general use over a period of years. The Bulkley[19] chart published in 1926 is shown schematically in Fig. 10. It appeared in the ASHVE Guide from 1926 through 1938 and a revised version continued in the Guide from 1939 through 1941. Abscissa and ordinate are dry bulb and dew point temperatures, respectively. Scales were approximately semi-logarithmic to provide a more uniform accuracy of reading over the range of temperature and humidity. The scales were also adjusted to convert the saturation curve to a straight line. Total heat (enthalpy), specific volume and moisture content were read from auxiliary curves and projected to vertical scales.

The E. Vernon Hill chart, first copyrighted in 1920, preceded the Bulkley chart. It was similar in form to Fig. 10, but with the triangle rotated through 135 deg to place the hypotenuse at the base. Numerous auxiliary scales were arranged along the three sides. I have found no record of the Hill chart having been published, although it was given wide distribution by the E. Vernon Hill Company and was considered by many users to be more convenient than the Bulkley chart.

Both the Bulkley and Hill charts with non-lineal scales for moisture content and enthalpy (or dry bulb temperature) were unsuited for graphic presentation of air conditioning problems. The desire to cover a wide temperature range with uniform accuracy has led to numerous charts with semilogarithmic and other non-lineal coordinates, but all have found only limited use in the air conditioning or refrigeration fields.

(*Continued on page* 102)

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R. C. CROSS NOW ASHRAE EXECUTIVE SECRETARY SUCCEEDS A. V. HUTCHINSON

A. V. Hutchinson

R. C. Cross

President Arthur J. Hess of ASHRAE has announced the appointment by the Board of Directors of Robert C. Cross as Executive Secretary of the Society, effective July 1.

Mr. Cross succeeds Aubry V. Hutchinson, who now becomes Executive Secretary Emeritus.

"Since the merger of its predecessor Societies ASHAE and ASRE last January," said Mr. Hess, "we have felt the need for a single administrative head to govern all staff activities at New York headquarters. Mr. Cross, as former Executive Secretary of the American Society of Refrigerating Engineers, brings to the combined organization an impressive record of professional achievement and experience in industry, as well as Society affairs.

"Mr. Hutchinson has served the other predecessor group, American Society of Heating and Air-Conditioning Engineers, as Secretary and Manager of Publications with loyalty and devotion over a period of more than 37 years," continued Hess. "As Executive Secretary Emeritus, he will, in a consulting capacity, bring to bear his long experience on the more challenging problems facing our newly-merged organization today."

Mr. Cross was appointed Executive Secretary of ASRE in December, 1954. Prior to this he was assistant manager of the merchandising testing and development laboratories of Sears Roebuck and Company for four years. Earlier affiliations include serving as fuel engineer, Battelle Memorial Institute; assistant fuel engineer, U. S. Bureau of Mines, Pittsburgh Station. From 1925 to 1935 he was with the H. B. Smith Company as test engineer and later as supervising engineer.

Mr. Hutchinson, who has been Executive Secretary of ASHRAE since the merger of ASHAE and ASRE last January, joined the staff of the American Society of Heating and Ventilating Engineers in 1922 as Manager of Publications. He was appointed Secretary in 1926 and Executive Secretary in 1950. When the Society name was changed to ASHAE he continued as Executive Secretary and Manager of Publications.

He preceded his 37-year career with the Society by entering the publishing field with the David Williams Co., New York, in 1914-15. He then served from 1916-17 as assistant and then associate editor of Metal Worker, Plumber and Steam Fitter in New York and as western editor for Sheet Metal Worker and Heating Engineer in Chicago from 1920-21.

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It is a 4-part problem

A. T. BOGGS, III
ASHRAE Technical Secretary

Why Standardization?: The Standards Engineers Society has announced its Eighth Annual Meeting at Boston. This will be a 2-day program, September 21 and 22, to study the question "Why standardization?" There will be speakers from top management and operating levels of industry, government, educational and research institutions. The program planned is divided into four areas: philosophy, research, education, and management.

ASA B3.11-1959: The American Standard Method of Evaluating Load Ratings for Ball and Roller Bearings has been announced by ASA. Copies are available from Dept. PR 81, 70 East 45th Street, New York 17, N. Y., at $1.75 per copy. The standard provides a uniform capacity rating system for the bearings made by all manufacturers. Uniform test procedures and statistical methods for determining load-carrying capacity and expected fatigue life for both ball and roller bearings are established. Dynamic and static capacity of radial and thrust bearings are covered in the standard and in addition to general definitions, it includes formulas for calculating such characteristics of bearings as bearing life, static equivalent load, etc. The new bearings standard was approved by associations of bearing producers as well as users, engineering societies, and by several government agencies.

Nema: Nema Standards Publication No. DC 3-1959, covering room thermostats, is available from Nema headquarters, 155 East 44th Street, New York, N. Y., at 40c per copy. This publication describes certain constructional details, ratings and methods of rating, sensitivity and methods of determining sensitivity of all types of alternating-current room thermostats, including heating, cooling, heating-cooling and electric heating thermostats.

ASHRAE: The ASHRAE Standards Committee has approved the proposed Standard 30P Methods of Testing for Rating Liquid Chilling Packages. The Board of Directors by letter ballot has recommended that this standard be published in the JOURNAL and submitted for consideration by the membership. The standard will appear in a future issue of the JOURNAL.

ARI: The July edition of the "Directory of Certified Unitary Air-Conditioners" is available from ARI. This edition lists rating data on 1611 models of equipment manufactured by 41 companies participating in the ARI certification program. To date, 47 companies have signed contracts with ARI to test and rate their unitary models according to applicable ARI standards. These companies represent over 80 per cent of the total industry shipments of unitary equipment. Air conditioners covered by the certification program include all types of central residential air-conditioners and many unitary packages used in commercial and industrial establishments, but not room air-conditioners, heat pumps, or large field-assembled systems. The top capacity of units in the program is 135,000 Btu/hr. Copies of the directory are also available to the public through equipment dealers and Better Business Bureaus.

"Only standardized products continue to improve, provide the most favorable selling prices, reduce the funds tied up in inventory, and contribute to universal improvement and facility of operations." – Charles W. Bryan, Jr., Vice President, Pullman, Inc. (ASA Newsletter No. 75, May 1959).

ASA: The ASA Director of Public Relations reports that representatives of 24 national organizations recommended July 7 that the American Standards Association initiate a project to develop standards for mobile homes and travel trailers. The action was taken at a general conference called at the request of the Mobile Homes Manufacturers Association and the Trailer Coach Association (West Coast).

The purpose of the standard is to provide a uniform national code which will serve the needs of the makers of the mobile homes. the communities which must accommodate these units and the owners of mobile homes.

Lack of national standards for mobile homes may find the mobile home builder and owner faced with varying codes or installation requirements throughout the country.

With an American Standard as a nation-wide guide for mobile home codes, manufacturers could build their units to conform to this standard of national acceptance.

A standard is approved as an American Standard only if it has

(*Continued on page* 85)

Meetings ahead

August 9-12—3rd National Heat Transfer Conference and Exhibit, University of Connecticut, Storrs, Conn.

August 19-26—10th International Congress of Refrigeration, Copenhagen, Denmark.

September 2-4—Cryogenic Engineering Conference, University of California, Berkeley, Calif.

September 25-29—American Meat Institute, Palmer House, Chicago, Ill.

October 5-7—American Gas Association, Annual Convention, Chicago, Ill.

October 30-November 2 — Refrigeration Service Engineers Society, Annual Convention, Atlantic City, N. J.

November 2-5—11th Exposition of the Air-Conditioning and Refrigeration Industry, Atlantic City, N. J.

November 9-13 — National Electrical Manufacturers Association, Annual Meeting, Atlantic City, N. J.

November 17-19 — Building Research Institute Conference, Washington, D. C.

December 3-5 — National Warm Air Heating and Air Conditioning Association, Annual Convention, St. Louis, Mo.

December 26-31 — American Association for the Advancement of Science, Annual Meeting, Chicago, Ill.

February 1-4 — American Society of Heating, Refrigerating and Air-Conditioning Engineers, Semiannual Meeting, Dallas, Texas.

February 1-4—2nd Southwest Heating and Air-Conditioning Exposition, Dallas, Texas.

March 6-10 — National Association of Frozen Food Packers, 19th Annual Convention-Exposition, Chicago, Ill.

May 1-4—Air-Conditioning and Refrigeration Institute, Annual Meeting, Hot Springs, Va.

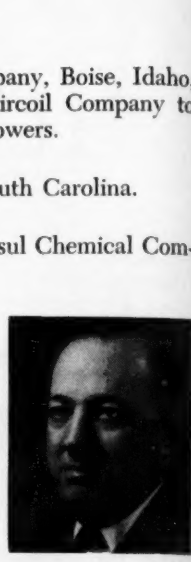
June 13-15—American Society of Heating, Refrigerating and Air-Conditioning Engineers, 67th Annual Meeting, Vancouver, B. C.

People

H. George Richardson, of the Richardson Equipment Company, Boise, Idaho, was recently appointed representative of the Baltimore Aircoil Company to handle sales of their evaporative condensers and cooling towers.

Charles M. Colyer is now representing Sterling, Inc., in South Carolina.

John K. Worthington will work from a Chicago office as Ansul Chemical Company's refrigeration sales representative in that area.



Bernhard Willach has been elected Vice President for Engineering, Marsh Instrument Company. The holder of many patents on pressure gauges, thermometers and solenoid valves, he received his Mechanical Engineering degree from Cologne University, Germany. For the past 17 years, he has been Chief Engineer of Marsh.

H. R. Roth, remaining in Toronto, is now General Sales Manager, Engineered Products, American-Standard Products (Canada) Ltd. For twenty-two years Toronto District Manager for Canadian Sirocco Products, he is succeeded in that position by **W. J. McLean,** most recently manager of the Vancouver Sales Office, Engineered Products.

H. J. Angstadt becomes manager of Keasbey & Mattison Company's St. Louis factories.

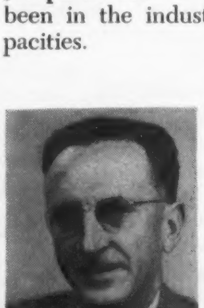
J. W. Hosler becomes marketing Manager for Kewanee and Nesbitt product lines, American-Standard Industrial Div.

A. James Hackl will be located in the main office of Worthington Corporation's Air Conditioning and Refrigeration Div, as he becomes General Manager.

Dr. Beatrice A. Hicks, President of Newark Controls Company, will tour selected South American countries next March as a part of the National Society of Professional Engineers Project Ambassador. She was chosen, along with her husband, **Rodney D. Chipp,** Director of Engineering of ITT Communication Systems, Inc., from among more than 2000 professional engineers who expressed an interest in this assignment.

James Hackbarth joins Drayer Hanson's sales engineering force with several years' experience with contracting organizations handling York products.

Joseph H. Hoff is now Factory District Manager of Payne Company. He has been in the industry for 12 years in production, engineering and sales capacities.



Hans H. Kohlenberger, founder and President of Kohlenberger Engineering Corporation, manufacturers of industrial refrigeration equipment, died at the age of 62, of cancer. Active in civic affairs, he served as mayor of Fullerton, Calif., home of his company, from 1938 to 1946, and as a member of the city council. He had been a board member of the Metropolitan Water District from its inception. A member of the National Association of Practical Refrigeration Engineers and the former ASRE, he was a licensed mechanical engineer in the state of California.

Charles A. Andreas has joined American-Standard Export Marketing Department as Sales Engineer for their industrial line. For the past year prior to his present connection, he was regional manager, middle east, for J. I. Case International.

Lawrence Faust is now District Manager of the Kansas City, Mo., sales territory of Mueller Brass Company. He has been sales representative since 1956.

H. R. McCombs' Supply Company of Denver has been named sales representative for Marlo Coil Company air conditioning and heat transfer products.

Walter A. Grant, second Vice President of ASHRAE and a vice president of Carrier Corporation, has been named Director of Engineering of the latter, in which capacity he will be responsible for the coordination of research, development and related activities throughout the corporation. Educated at Amherst College and Columbia University, Mr. Grant is an authority in the field of air conditioning and has been responsible for many advances in aerothermodynamics, absorption refrigeration and heat transfer since joining Carrier in 1928. In addition to writing many technical papers and magazine articles, he is a co-author of a textbook on air conditioning.

William R. Rinelli, with Ansul Chemical Company for 24 years, has been appointed General Manager of its Chemical Products Div, giving him direction over the functions of chemical production, sales and research. Holder of five patents on various methods and products pertaining to chemical phases of refrigeration and the author of chapters in "Refrigeration Data Book" and "Encyclopedia of Chemical Technology," as well as of numerous articles in refrigeration and chemical journals and pamphlets on company products, Mr. Rinelli joined Ansul as a research chemist, after receiving a degree in organic chemistry from the University of Wisconsin. Since then he has been Assistant Director of Research and Development, and, most recently, Coordinator of Product Planning.

Richard M. Toucey, formerly manufacturer's representative in the Pittsburgh area, is now representing American Air Filter Company in the same territory.

Duane D. Pearsall, President of the Pearsall Company, has been appointed representative for air conditioning products in Colorado and Southern Wyoming by Recold Corporation. A past President of the Rocky Mountain Chapter of former ASHAE, he is a member of the Colorado Engineering Council.

B. W. Moreland, continuing to head all manufacturing operations as in the past, has been elected Vice President of Copeland Refrigeration Corporation. Coming to the firm in 1958 after seven years in charge of compressor manufacturing at General Electric, ten years at Carrier Corporation and five years at Worthington Corporation, Mr. Moreland's technical organization affiliations include the American Welding Society and the American Society for Advancement of Management.

Wilbur S. Miller is now Manager, Marine Sales, for York Div of Borg-Warner Corporation. He has been manager of sales development.

William P. Tennity of Tennity & Company, Inc., Los Angeles, has been appointed to handle the Baltimore Aircoil Company, Inc., line of evaporative condensers and cooling towers.

Ben M. McDougall is now Field Sales Manager, Baltimore Aircoil Company, Inc. In his former position, he was General Sales Manager, Kennard Corporation.

Robert W. Gentry, with Temprite Products Corporation for the past eight years in sales and application engineering, has been appointed direct factory sales representative in Ohio. He will handle his company's complete line of products: self-contained and remote type water coolers, carbonators, oil separators and accessories.

William D. Graham, Jr., formerly Manager, Eastern Sales Region, is now Vice President in the sales div of Trane Company, and will be in charge of all Trane sales offices in the United States.

Others are saying—

that . . . . . close environmental control at Abbott Laboratories' experimental farm is essential for studying the effects of various feeds on poultry and swine. Because the sensible and latent heat outputs of these animals vary so widely under different conditions, a careful evaluation of design requirements was made before deciding how the close ventilation and temperature control could be achieved. *Heating, Piping and Air Conditioning, June 1959, p 131.*

that . . . . . . sufficient practical evidence points to the benefits of liquid circulating systems with ammonia refrigeration. Power savings at the compressor by eliminating excessive superheat and slopover are considered more important than the savings possible through more positive circulation on the low side. A discussion of what actually occurs in the evaporator in terms of types of boiling, heat transfer, types of flow, the liquid contents of the coil and pressure drop. *Industrial Refrigeration, June 1959, p 11.*

that . . . . . . low, intermediate and high temperature hot water heating system operating temperatures and design temperature drops have definite bearing on the selection of the most economical design for each application. *Heating, Piping and Air Conditioning, June 1959, p 116.*

that . . . . . . the use of air as refrigerating agent in the vortex temperature separators (Ranque tubes) leads to considerably larger energy losses than with the ordinary methods of mechanical refrigeration. The objective of studies carried out at the Bombay Institute of Engineering consisted of the development of a simplified design for a vortex separator and the production of the lowest possible temperatures at the cold end of the tube at low air pressures.

By additional separation of the air at the cold end the vortex separator could be considerably simplified and lower temperatures attained. *Kholodil'naya Technika (Refrigerating Techniques), No. 2, 1959, p 29 (in Russian).*

Candidates for ASHRAE Membership

Following is a list of 117 candidates for membership or advancement in membership grade. Members are requested to assume their full share of responsibility in the acceptance of these candidates for membership by advising the Executive Secretary on or before August 31, 1959 of any whose eligibility for membership is questioned. Unless such objection is made these candidates will be voted by the Board of Directors.

Note: * Advancement † Reinstatement

REGION I

Connecticut

STERNS, JESSE, Vice-Pres. & Gen. Mgr., Norwalk Co., Inc., South Norwalk.

Massachusetts

CHANDLER, C. B., Owner, Chandler Heating Service Co., Melrose.
MALATESTA, W. J.*, Engr., Polaroid Corp., Cambridge.
MALONEY, H. J., Mech. Designer, Buerkel & Co., Inc., Boston.

New Jersey

CONTOS, SOTIRIOS, Design Engr., A. Pellegrini & Assocs., East Orange.

New York

BONCZYK, J. A., Engr., Eastman Kodak Co., Rochester.
FRIEFELD, ARTHUR, Bld. Engr., International Business Machines Corp. Research Div., Yorktown Heights.
FLYNN, J. J., JR., Sales Engr., Industrial Div., American-Standard Schenectady.
LOUER, R. G., SR. Sales Engr., Powers Regulator Co., Syracuse.
MAGEE, J. B., Pres., J. B. Magee Assocs., Inc., Buffalo.
MARINER, E. T., Sr. Sales Engr., Powers Regulator Co., Syracuse.
PAINTER, ERNEST, Stationary Engr., Rochester General Hospital, Rochester.
RITCHIE, D. A., Design Draftsman, Heat-X, Inc., Div of Dunham-Bush, Inc., Brewster, N. Y.
SCHOEN, D. D.†, Mech. Proj. Engr., Voorhees Walker Smith Smith & Haines, New York.
SCHOEN, E. H., Estimator & Sales Trainee, Associated Thermal Products, Inc., New York.
SOTO, R. P., Proj. Engr., Empress de Frigorificos, New York.
STREIT, G. L., Repr., Slant-Fin Radiation Corp., Richmond Hill.
SWARTOUT, H. J., Engr., Eastman Kodak Co., Rochester.

Rhode Island

DE PALMA, VITO, Proj. Engr., Fram Corp., East Providence.

Vermont

GRATIOT, J. P., Owner, Gratiot Engineering Co., Woodstock.

REGION II

Canada

BOIVIN, WILFRED, Bill Boivin Plumbing & Heating, Ltd., Eastview, Ont.
BOWERMAN, E. L.†, Mech. Design Engr., Hydro-Electric Power Commission of Ontario, Toronto, Ont.
BRYAN, W. C., Owner & Mgr., W. Bryan Plumbing & Heating, Toronto, Ont.
CANBY, E. B., Cons. Engr., Welland, Ont.
CRAIG, K. N., Partner, Ball, Short & Co. Ltd., Willowdale, Ont.
GRAY, I. F., Asst. Gen Mgr., Penn Controls Ltd., Scarborough, Ont.
HARTMAN, ANDREW, Pres., Hartwil Sheet Metal Co., Toronto, Ont.
HOGSBRO, JORN, Mech. Engr., Dept. of Public Works of Canada, Ottawa, Ont.
KISHCHUK, B. W., Design Engr., Adjeleian, Goodkey, Weedmark & Assoc. Ltd., Ottawa, Ont.
LEGARE, R. G., Sales Engr., Honeywell Controls, Ltd., Ottawa, Ont.
LINE, P. W., Repr., Vapor Heating (Canada) Ltd., Toronto, Ont.
LORIMER, D. A., Dist. Sales Mgr., Ferro Metals (Ottawa) Ltd., Toronto (Scarboro) Ont.
LOUCKS, P. A., Repr., Trane Company of Canada, Ltd., Toronto, Ont.
McCARTHY, P. B., Estimator, Universal Sheet Metals, Ltd., Toronto, Ont.
McMINN, G. F., Sales Engr., Ferro Metals (Ottawa) Ltd. Toronto (Scarboro), Ont.
MILNE, F. W., Hgt. & Vtg. Designer & Chief Draftsman, J. F. MacLaren Assocs., Toronto, Ont.
MITCHELL, E. R., Head, Mech. Engrg. & Combustion Sec., Fuels Div., Dept. of Mines & Technical Surveys, Ottawa, Ont.
NARVEY, SYDNEY*, Sr. Design Engr., Canadian Kodak Co., Toronto, Ont.
ROBB, DAVE, Sales Mgr., Power Plant Equipment, Ltd., Toronto, Ont.
RUSSELL, C. R., Sales Mgr., Rocamora Bros., Toronto, Ont.
SEIGNUER, B., Mgr., Mech. Contrs., Craftmaster Heating Co., Winnipeg, Man.
SHORE, M. V., Chief Mech. Designer, M. A. Konforti, Cons. Engr., Toronto, Ont.
SMITH, F. J., Sales Repr., John Thompson-Leonard, Ltd., Toronto, Ont.
SMITH, W. P., Sr. Mech. Engr., McGregor & Beynon Ltd., Toronto, Ont.
SPECK, S. J., Sales Repr., Sheldons Engineering Ltd., Toronto, Ont.
TAMBLYN, R. T.*, Pres., R. T. Tamblyn & Assocs., Toronto, Ont.
THORPE, J. T., Design Engr., A. D. Margison & Assocs., Toronto, Ont.
WHITEMAN, R. D., Sales Mgr., York-Shipley of Canada, Toronto, Ont.
WILSON, D. A., Vice-Pres., Hartwill Sheet Metal Co., Toronto, Ont.

REGION III

District of Columbia

KANNAPELL, C. C., Sales Engr., American Air Filter Co., Inc., Washington.

Pennsylvania

WEIK, R. T., Hgt. Engr., Weil-McLain Co., Levittown.

REGION IV

Florida

MOREHEAD, L. C., JR.*, Office Engr., Hicks & Ingle Co., West Palm Beach.
SOWELL, H. T., Owner, H. T. Sowell Radio & Refrigerating Service, Chipley.

Georgia

GREEN, D. L., Chief, Mech. Sec., Corps of Engineers, U. S. Army, Thunderbolt.

North Carolina

FAGGART, H. M., Engr., Buensod- Stacey, Inc., Charlotte.
McDOWELL, D. E., Sales Engr., Powers Regulator Co., Charlotte.

REGION V

Illinois

McCONNELL, M. D., Chief Engr., A. W. Cash Co., Decatur.

Indiana

HAAG, F. A.†, Gen. Mgr., Bendix-Westinghouse Automotive Air Brake Co., Evansville.

Ohio

BRODERICK, T. N., Sales Engr., Delco

Products Div, General Motors Corp., Dayton.
SCHUMANN, R. J., Sales Engr., Kuempel Co., Columbus.
SECK, W. G., Executive Engr., Hoover Co., North Canton.
SKEATS, A. E., Supvsr., Fan & Coil Sec., Applied Machinery & Systems, Airtemp Div, Chrysler Corp., Dayton.
YOUNG, H. E.*, Asst. Engr., Nitrogen Div, Allied Chemical Corp. Ironton.

REGION VI

Illinois

STEWART, RALPH,* Mech. Engr., Great Lakes Plumbing & Heating Co., Chicago.

Michigan

BRZEZINSKI, JOSEPH, Chief Engr., Quincy Products Div, Stubnitz Green Corp., Quincy.
FICHTER, F. L., Engr., Behler Young Co., Grand Rapids.
KIDDER, G. F., Proj. Engr., Acme Industries, Inc., Jackson.
PEARCE, R. D., Pres., Pearce Heating & Welding Co., Detroit.
STICKNEY, R. E., Pres., J. A. Temple Co. Inc., Kalamazoo.

Wisconsin

SCHULTZ, F. C.†, Design Tech., R. D. Rodwell & Assocs., Inc., Milwaukee.
WEBER, G. F., JR., Engr., R. D. Rodwell & Assocs., Inc., Milwaukee.

REGION VII

Alabama

GREENE, R. E., SR., Chief Bldg. Engr., Gulf, Mobile & Ohio R.R. Co., Mobile.

Louisiana

WALTERS, G. L., JR.*, Dist. Repr., York Corp., New Orleans.

Missouri

CARMONDY, T. J., JR., Repr., Airtherm Manufacturing Co., St. Louis.
COON, F. G., Gen. Mgr., A. P. Equipment Co., St. Louis.
GYGAX, E. E.*, Pres., Ozark Engineering & Equipment Co., St. Louis.
MEDEWITZ, JOACHIM, Engr., Marlo Coil Co., St. Louis.
WULFSON, V. S., JR., Sales Engr., Armstrong Cork Co., Kansas City.

Tennessee

BURGER, W. O., JR., Design Engr., I. C. Thomasson & Assocs., Nashville.
CUNNINGHAM, J. P., Mgr., Southern Sales Co., Nashville.
FOSTER, B. W., Pres., Foster & Wood, Inc., Nashville.
GREEN, W. R., Engr., John W. McDougall Co., Inc., Nashville.
HAILEY, J. E.†, Owner, James E. Hailey Co., Nashville.
HICKERSON, FAULKNER, Partner, Burkhalter-Hickerson & Assocs., Nashville.
MYERS, W. D., Hgt. & A-C Engr., Nashville Gas Co., Nashville.
POTTER, J. R.*, Sales Engr., R. E. Gardner Co., Nashville.
TUPPER, V. S., JR., Owner, Vernon S. Tupper Co., Nashville.
WHITE, J. B., Engr., I. C. Thomasson & Assocs., Nashville.
WILSON, J. W., Owner, John W. Wilson Co., Nashville.

REGION VIII

Texas

BOEN, V. D.†, Estimator, Har-Con Engineering, Inc., Houston.
MCMURRY, T. R.*, Engr., General Engineering Corp., Fort Worth.

REGION IX

Colorado

NASH, R. C.†, Indus. Engr., Air Purification Co., Denver.

New Mexico

KOLLMAN, W. L.*, Mech. Engr., U.S. Corps of Engineers, Albuquerque.

Utah

HANSEN, J. R., Repr. Insulation Div., Johns-Manville Sales Corp., Salt Lake City.

REGION X

California

BELLMAN, J. V.†, Sales Mgr., Climate Conditioning Co., Stanton.
DEILGAT, C. H., Dist. Mgr., Burke & Co., San Diego.
GOSLIN, C. H., Designer, Climate Conditioning, Stanton.
LIPSHULTZ, MAX,* Asst. Chief Mech. Engr., J. S. Hamel, Engineer, Inc., Burbank.
RELF, W. J., Engr., Pahl-Harry Co., Stockton.
ROSENBLUM, LAWRENCE, Sr., Mech. Engr., Ralph M. Parsons Co., Los Angeles.
SCHUMACHER, E. W.*, Engr., Advance Refrig. Equip. Co., Corona.
SIEGFRIED, G. E., Draftsman, W. L. Donley, Mech. Engr., Fresno.
SLOAN, A. L., Sales Mgr., M. Schlom & Sons, Los Angeles.

Washington

MCCOY, C. F., Mech. Designer, Gray & Osborne, Yakima.
NORTON, R. E., Supvsg. Gen. Engr., U. S. Air Force, 5010th Installations Squadron, Seattle.
STINSON, R. C., Proj. Engr., John Graham & Co., Seattle.

FOREIGN

Australia

HARRIS, L. A., Chief Engr., Stephenson & Turner, Melbourne.

England

HARRISON, ERIC, Engr., G. N. Haden & Sons, Ltd., London.

France

CRENN, RAYMOND, Engr., Chantiers De L'Atlantiqua (Penhoet-Loire), Paris.

Hong Kong

DIXON, E. F., Asst. Engr. Mgr., Dairy Farm, Ice & Cold Storage Co.

Iraq

COTTELL, L. W.*, Tech. Mgr., African & Eastern (N.E.) Ltd., Baghdad.
GRAHAM, B. J., Tech. Dept. Mgr., African & Eastern (N.E.) Ltd., Baghdad.

Peru

COSTA, A. V., Engr., Mercantil Electra, S. A., Lima.

S. India

O'BRIEN, D. M., Chief Engr., M. S. Spencer & Co., Ltd., Madras.
NITHYANANDAM, C. R., Foreman, Government Milk Factory, Madras.

Venezuela

FLEISCHER, THOMAS, Estimating Engr., Acondaire S. A. (Trane) Caracas.

Holland

MENNES, F. S., Engr., Bronswerk N. V., Amsterdam.

IT IS A 4-PART PROBLEM

(*Continued from page* 81)

been accepted by a consensus of all parties interested in it. The Mobile Homes Manufacturers Association and the Trailer Coach Association presented to the conference a standard for electrical, heating, and plumbing equipment for consideration of approval as an American Standard by the general acceptance method of ASA.

Lack of consensus at the conference for approval of the MHMA standards led to the recommendation that the work be handled by a sectional committee set up under regular ASA procedures. Such a committee would be responsible for the development of standards relating to construction and equipment of mobile homes and travel trailers. The conference held at the ASA office in New York recommended the project be jointly sponsored by the Mobile Homes Manufacturers Association and the Trailer Coach Association.

What ASHRAE Chapters are doing

MINNESOTA and TWIN CITY . . . Application of Vibration Isolators for Ventilation, Air Conditioning and Refrigeration Equipment was the topic recently when Samuel Kahn, Vibration Eliminator Company, addressed these chapters, meeting jointly.

BIRMINGHAM . . . Olivia Burkey planned to address these members in June on Taking the Mystery out of Water Treatment, a talk which she originally gave at the 65th Annual Meeting of ASHAE in Philadelphia. Her paper later appeared in the May issue, ASHRAE JOURNAL.

NEW MEXICO (H) . . . Kenneth Finders and Joseph Moody, Sandia Corporation, gave a talk on their firm, entitled Little Bureau of Standards, at a recent meeting here.

MEMPHIS . . . "Air Cooled Condensers vs. Cooling Towers" was the subject of a panel discussion held at the June meeting of this group. There seemed to be a general feeling of rather limited application for large size air-cooled condensers.

GOLDEN GATE (H) . . . At the last meeting, held early in June, these men heard Lew Pollack, Carrier Corporation, and Gerald Yaffey, Worthington Corporation, discuss the application problems of centrifugal water chillers.

MONTREAL . . . Contract bidding, discussed in forum, was soundly debated at the May meeting of this chapter. H. G. S. Murray moderated panel members Robert Layton, Robert Clapperton, W. E. Jarvis, Roland Carrigan, D. J. McIntyre and J. P. Fitzsimons.

The discussion centered around the "shopping" practices of many contractors with respect to manufacturers and subtrades.

The panel concluded that an effective means of limiting or reducing the shipping practices would be the use of base bid specifications, listing the names of suppliers at the time of tendering, and the use of the bid depository.

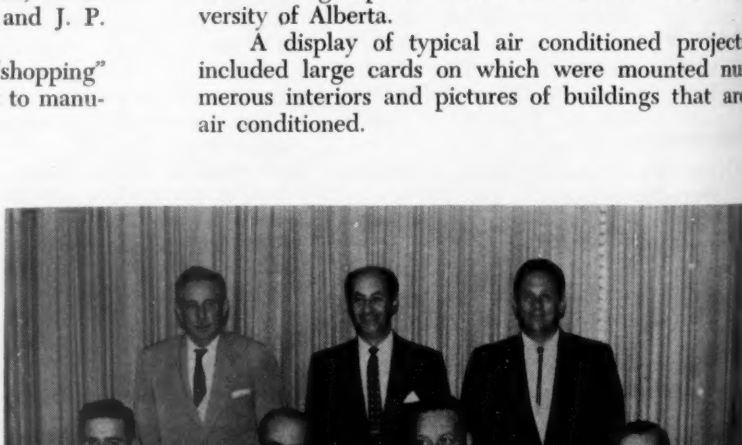
It was felt that if the manufacturers thought that a bid depository should be set up for the major items of equipment, then it was up to manufacturers to initiate and organize such a depository.

HOUSTON (H) . . . Speaker of the mid-June evening was John Traynor, Johnson Service Company, who covered the Do's and Don't's of Temperature Control.

MASSACHUSETTS (H) . . . The operation, history, finances, and interrelationships of the Engineering Societies of New England with the other unity organizations of engineers, including ASHRAE, received the attention of speaker James Adams at recent meeting here. Mr. Adams is President of ESNE.

NORTHERN ALBERTA . . . Over 200 people attended the Air Conditioning Symposium sponsored by this chapter in May. John H. Fox, Vice President, Honeywell Controls, and first Treasurer, ASHRAE, presented Economic Studies; Herbert A. Scott, Manager, Manufacturer's Life, covered the Investor's Viewpoint; Percy M. Butler, Vice President and General Manager, Angus, Butler & Associates, Ltd., spoke on Definitions and Descriptions; and Daniel W. Thomsen, Consulting Mechanical Engineer, reviewed Design Considerations. Moderator of the group was David Panar, Professor, University of Alberta.

A display of typical air conditioned projects included large cards on which were mounted numerous interiors and pictures of buildings that are air conditioned.



In preparation for the 1959-1960 season, the South Florida Section elected these officers: seated, l to r, Vice President A. R. Martin, President R. Douglas Hazen, Secretary Arman Cowan, and Treasurer Albert F. Plaag. The Board of Governors, back row, includes J. W. Hendricks, Stephen Shelton and Hugh Kirkpatrick.

Organizing under post-merger set-ups for the coming 1959-1960 season, some ASHRAE chapters already have selected their officers. The accompanying record adds to such information as has reached Headquarters. Other changes will be listed in later issues.

CENTRAL ARIZONA
Pres.–George Jackson
Vice Pres.–Jack R. Hight
Secy.–Stan Frederickson
Treas.–William Missemer

EVANSVILLE
Pres.–Richard E. Deaux
1st Vice Pres.–Robert E. Ahlf
2nd Vice Pres.–H. C. Shagaloff
3rd Vice Pres.–C. L. Herndon
Secy.–Don S. Phillips
Treas.–Louis C. Bond

NEW MEXICO
Pres.–Emmett Brazier
Vice Pres.–Roy P. Lee
Secy.–Vernon J. Stephens
Treas.–Henry Frankenfeld
Board of Governors–H. A. Garber
James Desilets
Warren Jones

RICHMOND
Pres.–G. J. Wachter
Vice Pres.–F. J. Weiss
Secy.–J. C. Turlington
Treas.–M. M. Alley
Board of Governors–H. A. Garber
C. H. Imel
G. W. Hallam

SAN FRANCISCO
Pres.–Thomas R. Simonson
Vice Pres.–Karl Guttman
Secy.–Rudolph C. Pribuss
Treas.–Donald A. Delaney
Board of Governors–L. E. Dwyer
J. D. Kniveton

SAN JOAQUIN
Pres.–John Lamborn
Vice Pres.–Roy C. Cody
Secy.–David Rodkin
Treas.–William Grotzke
Board of Governors–James Blaney
D. Lawrence

SOUTH FLORIDA
Pres.–R. Douglas Hazen
Vice Pres.–A. R. Martin, Jr.
Secy.–Armand Cowan
Treas.–Albert F. Plaag
Board of Governors–S. Shelton
H. Kirkpatrick
J. Hendricks

PARTS AND PRODUCTS

COOLING COIL CLEANER

Liquid concentrate designed to restore heat transfer and draft in air conditioning systems, Metalene is a chemical compound for cleaning coils and filters.

A blend of synthetic penetrants, when diluted with water it provides a safe, odorless, powerful solution for cleaning coil exteriors, permanent filters and blower fans. It is sprayed on and flushed off with garden hose.

A light film of the liquid applied after cleaning will inhibit rust. It is harmless to paint.

It may also be used as an adhesive to treat permanent type filters instead of oil.

Lester Laboratories, Inc., P. O. Box 4897, Atlanta 2, Ga.

CENTRAL CONTROL PANEL

Indicators for indoor temperature and humidity, outdoor temperature and barometric pressure are combined with an electric clock to make up this one-location Weather Station designed for mounting in the living area of the home.

Patterned after the Supervisory Data-Center for industrial use, this residential control panel measures 7⅝ by 14 in. and is recessed between studs on an inside wall. All wiring is low-voltage.

A specially designed thermostat, having neither an external temperature setting dial nor a thermometer, is used in conjunction with the station. Temperature adjustments up to 6 deg are made by turning a dial on the control panel. Adjustments in temperature setting of more than 6 deg are made by snapping off the thermostat cover and pushing a small knob located in the thermostat interior.

The electric clock provides automatic night-time set-back of temperature (affixed 5 deg), and morning pick-up for the comfort system. A special control switch will change this process.

Outdoor temperatures from −40 to 130 F are indicated on the panel. Capillary and bulb length is 20 ft. Alarm lights will indicate a clogged filter, need to reset compressor, oil burner or gas pilot light.

Two models provide automatic changeover from heating to air conditioning, and two provide semi-automatic changeover.

Minneapolis-Honeywell Regulator Company, Residential Div, 2747 Fourth Ave., S., Minneapolis 8, Minn.

PORTABLE INSULATION TEST SET

Tests of motors, generators, cables and control equipment for insulation leakage current and voltage breakdown may be made with the Hypotr Model 5205 Portable D-C High Voltage Test Set. The test voltage is continuously variable from 0 to 5000 volt dc, providing leakage current tests of insulation on every type of industrial equipment, ranging from those operating on 115 to 2500 volt ac power sources.

One indicating instrument meters the output voltage directly across the test terminals, and the other is for leakage current with a selection of four sensitivity ranges: 0-2, 0-20, 0-200, 0-2000 microamp. Leakage current as low as .05 microamp may be measured.

The self-contained power supply operates from a 115 volt ac line, utilizing selenium rectifiers to provide 5000 volt dc, with a high current output of 15 milliamp available.

Associated Research, Inc., 3777 W. Belmont Ave., Chicago 18, Ill.

FORCED-DRAFT BOILERS

Packaged commercial and industrial boilers feature forced-draft firing and a front-mounted control panel providing a selector switch for instant fuel change-over on combination gas and oil units.

Designated Square-Heat Type RF units, they cover a range of SBI ratings from 1010 to 5620 sq ft and water from 243 to 1350 mbh. The burner fires natural, mixed or L.P. gas or No. 1 or 2 fuel oil, or combination gas and oil. The burner and all controls are installed and wired at the factory.

In addition to conventional safety controls, an air-flow safety switch delays firing until the forced draft blower is operating at the correct speed.

American-Standard, Industrial Div, Detroit 32, Mich.

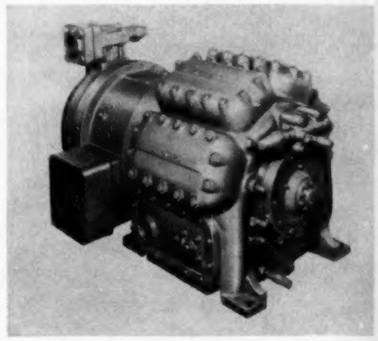
TEMPERATURE RESET SEQUENCE SWITCH

Consisting of an outdoor sensing bulb and a system for load transfer of up to six stages, actuated by variants of one deg if desired, this multiple compressor device protects the user against single compressor breakdown, and is designed for thermostatic control of air conditioning in auditoriums, churches, theatres, and other buildings where sudden load changes occur. Fast cycling results in close temperature tolerances.

George T. Hall Company, Los Angeles, Calif.

1750 RPM REFRIGERATION COMPRESSORS

Four-pole direct-connected motors eliminate the necessity of V-belts and sheaves in this line of hermetic and direct coupled drive units, designed to operate at 1750 rpm. Interchangeability of components between the field serviceable hermetic compressor and the coupled compressor reduces to a minimum the local inventory required to render replacement of all components subject to wear.



This line is available in six sizes ranging from 15 to 80 ton capacities.

Worthington Corporation, Harrison, New Jersey.

AIRBORNE WATER COOLER

Operable from standard 400 cycle three-phase power, this lightweight unit is designed specifically for airborne use. The Taskline water cooler is intended to answer airline problems of passenger demand while reducing costly ground servicing, supplying cooled drinking water at predetermined temperatures within five minutes after electrical power is supplied to the aircraft.

Task Corporation, 1009 E. Vermont Ave., Anaheim, Calif.

FLEXIBLE PIPE HANGERS

Basically spring-actuated counterbalances, these hangers are designed to provide constant load-supporting capacity for piping systems subject to expansion and contraction due to temperature changes. All main load-carrying parts are located at one end of the structure, permitting installation in congested locations. The overhanging spring assembly can be revolved at any angle about the load and support rods, permitting additional installation flexibility, and vertical distance between support and load connections is as short as possible, for installation where headroom is limited. In case of extreme headroom limitation, the turnbuckle and providing rod adjustment at the end of the support or load rods can be eliminated.

Counterpoise Constant Support Hangers are available in four basic types: single and double suspension models, a vertical model and a junior model.

Fee and Mason Manufacturing Company, Inc., Manasquan, N. J.

DUAL RECORDING THERMOMETER

Equipped with two thermal sensing elements and two pen mechanisms in the same body, Model TRH is designed to sense and record temperatures up to 1100 F, simultaneously in two locations. The pens operate on a two-hour differential to prevent interference in the event that both sensed temperatures are the same. Available with either electric or spring-driven chart drives, the thermometer has ten applicable scale ranges. Elements of the same scale ranges are interchangeable, regardless of the bulb type, allowing field replacement of elements.

Partlow Corporation, 525 Campion Rd., New Hartford, N. Y.

POSITIVE DRIVE BELTS AND PULLEYS

Molded teeth on the belt are designed to make positive engagement with mating axial grooves on the pulleys in this line, combining the advantages of the chain and gear with those of the belt. Available on drives up to 600 hp and from speeds under 100 fpm to over 10,000 fpm, these belts are adaptable to virtually every kind of power transmission drive, large or small.

Worthington Corporation, Harrison, New Jersey.

CENTRIFUGAL PUMP

Offering flexibility of application and conserving weight and space, this pump utilizes two metal stampings bolted together to form a housing which encloses a welded impeller assembly. With the same basic pump casing, a wide range of capacities becomes practical by varying the impeller design and the motor size.

The pump is available coupled directly to motor, extended from motor flange for special applications, and with the pump alone mounted on base for coupling to any power supply.

R. S. Corcoran Company, P. O. Box 1401, Mound at Brandon, Joliet, Ill.

FLAT QUARTZ PORTABLE HEATER

Rated at 1320 watt, the All-Radiant Portable features a flat quartz element designed to heat without dehydration of the air or creation of drafts. The unit is U.L. approved and comes with automatic thermostat, safety tip-over switch and pilot light.

Ampere Industries, 60 Boston St., Newark 3, N. J.

ELECTRIC AIR CONDITIONER

Increased capacity of from 10 to 14% and reduction in size characterize this unit, the design of which has been greatly simplified. Liquid indicator is used to measure the amount of refrigerant in the condenser coil, assuring the right amount of charge at all times. Both high and low pressure switches are used as standard equipment to protect the compressor and electrical components against excessive loads and overheating in the event of a low charge.

A 2-in-1 condenser coil is cited as being responsible for the increase in efficiency; after its normal job of converting hot refrigerant gas into a liquid, it after-cools the liquid approximately 20 deg.

Model 562 comes in three sizes rated at 24,000, 36,000 and 46,000 Btu/hr.

Bryant Manufacturing Company, Indianapolis, Ind.

DOW | INSULATION

STYROFOAM®

Key to permanently low operating costs

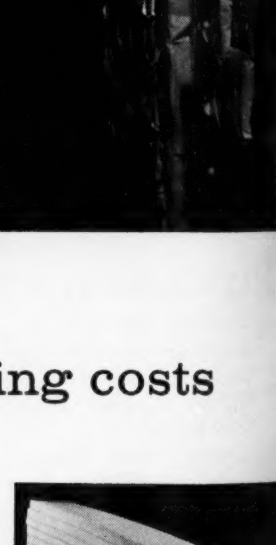
When Styrofoam* insulates low temperature space, the long term costs of operating refrigeration equipment tumble to a new low . . . and stay low, permanently! There's no loss of insulating efficiency with the passage of time, thanks to an unmatched combination of physical properties.

Here's a rigid plastic foam insulation with thousands of tiny, individual air cells in every cubic inch. This cellular structure provides an extremely low "K" factor plus high resistance to the passage of water and water vapor. With Styrofoam there's no water pickup . . . consequently its heat conductivity stays low. And when heat load stays at virtually the same low level over years of service, your equipment operating costs stay uniformly low, too!

And here's another important factor in low operating costs. Because Styrofoam won't freeze, swell or crack — won't permit ice formation, often the cause of buckled insulation—there's no need for periodic replacement and your equipment won't have to work overtime removing heat introduced during repair.

For more information, contact the Styrofoam distributor near you, or write THE DOW CHEMICAL COMPANY, Midland, Mich., Plastics Sales Dept. 2222JZ8.

*Dow's registered trademark for its expanded polystyrene



THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

RIBBON THREAD SEALER

Non-flammable and with negligible water absorption, Fluoro-Plastics Thread Sealant Ribbon #26 is manufactured for use on pipes, stud bolts, bungs and other threaded materials, acting as a compressible solid and molding itself to the threads. Of 100% Teflon in ribbon form, it can be used effectively at continued operating temperatures from −450 to +500 F, substantially retaining its physical properties within this range.
Fluoro-Plastics, Inc., 2417-X38 Federal St., Philadelphia 46, Pa.

DIAL THERMOMETERS

Available in 12 temperature ranges between −40 and +450 F, these thermometers are offered with a wide choice of special mountings including an adjustable angle type which permits facing the dial in any vertical position throughout a 200 deg arc. Standard equipment includes a 5-ft armored tube system with union connected copper bulb. Options include special materials for bulbs, sockets and tube systems. The units are also available with solid liquid filled tube systems with evenly graduated dials.
H. O. Trerice Company, 1420 W. Lafayette Blvd., Detroit 16, Mich.

BACTERIA-KILLING AIR FILTERS

Air filters which trap and kill germs have been introduced for medical, home, industrial and institutional use by this manufacturer, fitting all types of air conditioners, furnaces and air circulators, and available in 300 different models and sizes.

The filtering media consists of dry synthetic fibers bonded together to form a maze of dirt traps and treated with a germicidal agent. This cellulose acetate material is odorless, white, non-splintering and non-irritating. Use of a dry media ends the problems of cleaning oil scum from ductwork, caused by oil wetted fibers.
Fram Corporation, Providence 16, R.I.

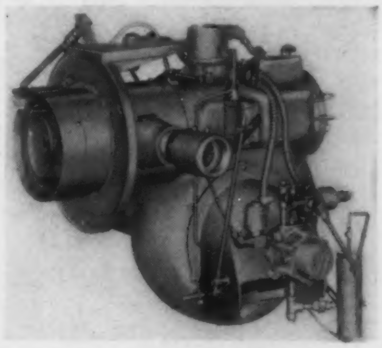
TWO-STAGE REFRIGERATION MACHINES

Designed specifically to provide chilled water for air conditioning of large buildings and factories, these 2-stage Tonrac refrigeration machines are also adaptable to heat pump applications. For applications requiring 400 to 800 ton operating capacity, the unit, designated Series 235, operates on Refrigerant-11.

The machines are powered by water-cooled hermetic motors, available for operation with 208 to 6600 volt current. The hermetic design avoids the need for shaft seals, field alignment of moving parts and multi-step foundations. Operating at 3600 rpm, impellers are directly driven and are supported on the overhung extended motor shaft, eliminating the need for speed gears.
American-Standard, Industrial Div, Detroit 32, Mich.

INVERTED FORCED DRAFT BURNERS

Fully automatic, these inverted forced draft power pressure burners are available in oil, gas and combination gas-oil units. Capacities, in appropriate sizes, range from seven to



thirty gph, or gas capacity of 1,000,000 to 4,200,000 Btu/hr. Shown in Type PCPSF, Size 3.
Ray Oil Burner Company, 1301 San Jose Ave., San Francisco, Calif.

LOAD LIMITING RELAY

Protection for motors of centrifugal refrigeration compressors from overload on start-up is provided by the V-26 Load Limiting Relay, designed for pneumatic control systems and capable of being used with all makes of compressors.

Connected in the control line to the suction damper operator, it limits the output capacity of the compressor to the full load motor ampere rating and can be adjusted for any current value between 3 and 7 amp. Since it is used with motors having many times this ampere rating, a current transformer is used to provide a current within these limits.

This relay may also be applied to fans, pumps, and electric heating systems.
Johnson Service Company, Milwaukee 1, Wisc.

AIR DEHYDRATOR

Manufactured for the extraction of moisture from compressed air lines, these devices make use of localized refrigeration to impart new dew-points to air supplies as low as required to preclude the precipitation of moisture in the process lines. Com-

pletely self-contained, with hermetically sealed refrigeration systems, they incorporate automatic non-shut-down defrost cycles without resorting to reverse cycle refrigeration and automatic rejection of water as collected. Various sizes are available to accommodate a wide range of cfm, pressures and temperatures of entering air.

Extract-O-Moist Manufacturing Company, P. O. Box 5852, Birmingham 9, Ala.

DUPLEX PUMP CONTROLS

Developed for control of motors on twin pump installations where two pumps operate either individually or in conjunction to provide the necessary pumping operation depending upon the pumping rates required, the combination type units provide a disconnect means for every motor, either through the use of a disconnect switch, fusible or non-fusible, or a thermal magnetic trip circuit breaker placed in series with the starter and the load. Claiming many advantages for the single enclosure over separate starters and disconnects, the manufacturer points out that all interior wiring is done at the factory, simplifying installation and maintenance.

As a safety feature, all combination Type DP Duplex Pump Controls have the front operated mechanism mechanically interlocked with the cover of the enclosure, making it necessary to disconnect the circuit before the door can be opened.

Non-combination types consist of two magnetic starters and a single relay for electric alternating mounted in one enclosure.

These controls are normally supplied with 3-pole construction for 3 wire, 2 or 3 phase power systems. Enclosures available include General Purpose Nema 1, for indoor use; General Purpose Nema 1 with neoprene gasket, for dusty locations, and Nema 2, Drip Tight, for use where excessive moisture is present.

Arrow-Hart and Hegeman Electric Company, 123 Hawthorn St., Hartford, Conn.

CENTRAL STATION AIR CONDITIONERS

Major design, performance and service-feature changes have been made to this manufacturer's line of central-station air conditioning equipment for single-zone applications. The line is now being marketed in 30 models, vertical and horizontal types, each type being available in capacities 500 through 35,000 cfm.

Featured is construction permitting full access from any exposed side of the unit, with an extra-large access door being provided. Citing a number of benefits, the manufacturer is internally mounting both motor and drive within the fan section. Purchaser has option of high velocity or velocity filter section.

Drayer-Hanson, Div of National-U.S. Radiator Corporation, 3301 Medford St., Los Angeles 63, Calif.

HEAT-SETTING LIQUID PLASTICS

Essentially a coating or molding compound which is in a liquid state under ordinary room conditions, this product can be converted to a structurally strong solid by heating to moderate temperature without pressure. Virtually no shrinkage occurs through the conversion process.

Unlike many paints, lacquers and most plastics, Logosol is custom formulated. For example, it can be made as a soft rubber-like elastic material, or as a hard, firm, rigid solid. It can have a high degree of abrasion resistance, resist acids, alkalies or other chemicals, provide high dielectric resistance for electrical insulation, or have many other purposes.

Bee Chemical Company, Logo Div, 12933 S. Stony Island Ave., Chicago 33, Ill.

HIGH-CAPACITY COOLING TOWER

Smaller and weighing less than conventional models of similar capacity, these towers utilize a new material which speeds transfer of heat to the air, and requires only one-fourth of the space occupied by the conventional grid construction.

This fill is made of pressed wood fibers in a porous honeycomb pattern impregnated with phenolic resins, which is resistant to aging, chemical deterioration and deposit of scale from the water.

Carrier Corporation, Syracuse 1, N.Y.

MULTIPLE TESTING UNIT

Equipped with three stainless steel test cells, each having a net test area of 14 cu in., this unit provides test temperatures adjustable from 0 to −20 F in Cell A, −35 to −45 F in Cell B, and −60 to −75 F in Cell C. A cascade refrigeration system equipped with ¾ and 1-hp accessible hermetic motor compressors provides the refrigeration for all three cells. Each compartment is individually controlled and operation is charted by individual recording thermometers. For minimum temperature variation, an 8-in. air circulator is provided for each area. Plexiglass inner lids cover each cell to minimize temperature loss and variation when any of the adjoining cells are open.

Cincinnati Sub Zero Products, 3932 Reading Rd., Cincinnati 29, Ohio.

SMOKELESS OIL BURNER

Applying proven principles of combustion currently being used in jet aircraft and rockets, this manufacturer has developed a compact hot water boiler to provide smokeless combustion at all air shutter settings, from full open to the permanent stop. The design of Zone-A-Matic boiler units results in an intensified flame pattern cited as achieving full combustion of the fuel particles in the combustion chamber proper, so that incompletely burned fuel particles do not enter the flue passages to be cooled and deposited as carbon on the flue surfaces.

Edwards Engineering Corporation, 101 Alexander Avenue, Pompton Plains, N. J.

FLEXIBLE METAL TUBING

Three grades of flexible metal tubing in an enlarged range of sizes and materials are now available from this manufacturer, for applications such as dust and fume collectors, suction and blower hose, blow-pipe and ventilating systems, refrigeration supply lines, armoring and shielding conduit, domestic and industrial space heaters, and hot air heater connections. Made with interlocked construction of strip metal in a choice of thicknesses from 0.010 to 0.034 in., this tubing is available in galvanized, cold rolled and stainless steel, and bronze.

International Metal Hose Company, Bellevue, Ohio.

AREA TRAVERSE UNIT

Both manually operated and remote controlled, these units provide detailed measurements of velocity, pressure, direction and temperature at any point on a given cross section of a flow duct or other piece of fluid flow machinery. Different types of primary probes can be utilized for measuring total pressure alone or total pressure, static pressure, pitch angle, yaw angle, and total temperature. They can be used conveniently to determine total flow or energy at a given fluid stream cross section by integrating the areas inside the contour lines. Direct measurements of efficiency of turbines, blowers and compressors may be made, and the thrust of jets can be measured directly.

United Sensor and Control Corporation, Box 127, Glastonbury, Conn.

BULLETINS

Safety Unit. Flame Failure Bulletin 523 explains the safety factor of a unit designed to eliminate explosions, and covers the unit's flexibility in application to oil, coal or gas installations. The flame failure safeguard reacts only to a flickering flame and is a constant monitor assuring maximum protection in a wide range of industrial or commercial combustion installations. Capsule descriptions of the principle of operation are included.
Photomation, Inc., 96 South Washington Avenue, Bergenfield, N. J.

Manual Fluid Flow Control. Design of instruments used for measuring and controlling fluids flowing at low rates makes them suitable for front-of-panel mounting or for mounting directly in pipelines, as described in Bulletin 18P. The Purge Rotameters are applicable to liquids and gases. Nine flow ranges are listed, all ob-tained in the same basic body through the use of interchangeable glass metering tubes and glass or stainless steel floats.

The smallest capacities available over a 10 to 1 range are 0.6 gph water, or 0.50 scfh of air (metered at 10 psig). Capacities of the largest units are 12 gph water, and 70 scfh of air (metered at 10 psig).

Described is the basic unit to measure and indicate flow, and the combination of it with a differential regulator to provide simplified automatic control of fluid rate of flow.
Schutte and Koerting Company, Instrument Div, Cornwells Heights, Bucks County, Pa.

Air-Over Fan Motors. In ratings of 1 to 125 hp, enclosed and explosion-proof, the motors described in Bulletin 2950 are designed for operation in ventilating systems, exhaust systems, cooling towers and all air moving installations where a motor drives a propeller or axial flow fan.

The bulletin gives application data for determining the motor hp rating required in an installation for various air velocities across the motor. Motor design utilizes air circulated in these installations to cool the motor.

Dimensions and data on recommended maximum fan weight, thrust and location are also given.
Louis Allis Company, 427 E. Steward St., Milwaukee 1, Wis.

Variable Speed Drives. Photographs of the basic types of variable-speed drives, and of a large variety of modifications are included in Bulletin 195 along with suggested applications and detailed information regarding hp, duty, mounting styles, enclosures and electrical characteristics.
Sterling Electric Motors, Inc., 5401 Telegraph Rd., Los Angeles 22, Calif.

Air Compressor. Designed to deliver clean air for applications involving one air line respirator or one air line hood, this compressor is capable of delivering 6 cu ft of air per min at 8 to 10 psi through lengths of hose up to 50 ft. As covered in Bulletin 1009-12, the M-S-A diaphragm type air compressor is presented with dimensional and constructional details, including such features as permanent lubrication, specially reinforced flexible diaphragms, stainless steel valves and large-capacity intake filters.
Mine Safety Appliances Company 201 North Braddock Avenue, Pittsburgh 8, Pa.

Packaged Air Conditioners. Complete air conditioning systems, in one package, are produced in several models ranging from 20 to 60 ton. These units feature complete one-side accessibility, with all controls and maintenance points on one side of the unit

so that it may be installed close to a wall. Construction details. dimensions, model designations, cooling capacities, compressor motor hp and other engineering information are covered in 8-page Bulletin 570.
Acme Industries, Inc., Jackson, Mich.

Installation Guides. Two booklets, one on packaged liquid coolers, and the other on condensing units and motor compressors, contain all essential data needed for installing the equipment. Complete with line drawings which show locations of units, various charts and tables, and instruction sheets, the guides provide the contractor with easy-to-read information.
Bell & Gossett Company, Morton Grove, Ill.

Force-Flow Chiller. For the refrigeration, circulation and closely controlled temperature of water, liquid chemicals or acids, or many types of corrosive or non-corrosive liquids, these force-flow packaged liquid chillers, as mentioned, may be used in scientific and laboratory work, product cooling during manufacture and other areas. They are in ¼, 1/3 and ½ hp sizes with air or water cooled condenser and will maintain bath temperatures in ranges from −30 to 75 F. Models with a temperature range of 15 to 75 F are equipped with corrosion resistant stainless steel type 316 evaporator and corrosion resistant Zytel nylon pump with stainless steel shaft and fittings.
Remcor Products Company, 321 E. Grand Ave., Chicago 11, Ill.

Nameplate Designing. Intended for use by the engineer, draftsman, or Standards Department personnel for use in designing nameplates for prototype of quantity production in the initial stage of product development, this 20-page booklet provides instructions on lettering, composition, rough layout, selection of materials, nameplate processes, steps in manufacturing, and check-off list for nameplate buyers.
H. G. Dietz Products Company, 12-16 Astoria Blvd., Long Island City, N. Y.

Thermistor Probes. Technical characteristics of interchangeable thermistor probes are given in this 6-page bulletin with sections on the advantages of thermistor based temperature measurement and control, and on application areas for this type of instrumentation.

The probes described are for use in Thermistemp remote reading Telethermometers and controllers, or for use as component transducers in specially designed instrumentation.
Yellow Springs Instrument Company, Inc., Yellow Springs, Ohio.

Analysis Instrument. Specifically developed for the laboratory analyst, Type 26-201A Chromatograph, as described in Bulletin 1831, is a compact instrument for the quantitative analysis of gases and volatized liquids. Based on the chromatographic principle of component separation by selective adsorption, solution, or reaction, the instrument utilizes the elusion method to produce complete separation.

The illustrated, 16-page booklet has sections on the principles of chromatography, applications, natural gasoline analysis, accessories, specifications and descriptions of the features of the instrument, which consists of two units, a control and an analyzer.
Consolidated Electrodynamics Corporation, Analytical and Control Instrument Div, 360 Sierra Madre Villa, Pasadena, Calif.

Industrial Gases. Production and commercial applications of such gases as oxygen, nitrogen, argon, helium, acet-
(Continued on page 103)

(*Continued from page* 50)

photograph was taken after more than three hours of continuous operation. Oil ripples appeared in the oil stream at the bottom of the horizontal leg but these ripples were nearly stationary. Their velocity was estimated at less than 1.0 in. per min. Above this oil stream the suction line was completely clear. Turbulence in the bends of the trap caused no more than a slight mist to form. The pool of oil at the bottom of the trap was about the same thickness as in Test No. 5 but in this case the surface of the pool was turbulent.

Some oil condensed at the surface of the pipe and just beyond the bend. No film appeared in the riser beyond this condensation. The system operated several hours without apparent change in crankcase oil level or without change in quantity of oil in the pool at the bottom of the bend. Again it must be concluded that the small quantity of oil in circulation must have traveled in the horizontal and vertical legs of the trap as a transparent colloidal dispersion.

Test No. 7. Fig 13 reveals the flow pattern of the oil in the transparent trap when the suction line vapor velocity was 670 fpm. The photograph was taken after more than 3 hr. of continuous operation of the system. The suction temperature and superheat were approximately the same as in Test No. 5 and Test No. 6. Oil ripples in the oil stream in the horizontal leg moved at about 2.0 in. per min. Only a small pool of oil still remained at the bottom of the trap but this pool was blown to the riser side by the vapor. Oil ripples moved slowly upward along the surface in the upward leg of the trap. At this velocity the vapor travel is sufficiently turbulent to cause condensation of oil by impingement along the surface of the pipe.

CONCLUSIONS

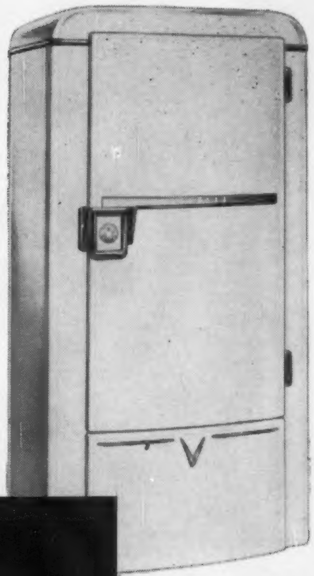
1. The study of oil flow in long horizontal suction lines was conducted at lower suction pressure, higher superheat at the trap, and a lower concentration of oil in the refrigerant than that of the performance of a "P" shaped trap at the bottom of a suction riser. The combination of these factors affect the oil flow pattern considerably and further work needs to be done to adequately separate their effects. It appears, however, that the concentration of oil in the refrigerant is the most significant.

2. At the low concentration of oil in the refrigerant of the second study 0.6% or lower it would be quite difficult to encounter an oil return problem, except by tapping into the bottom of a horizontal suction main or by improper drainage at the evaporator.

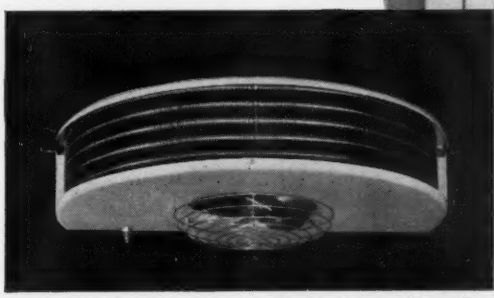
3. If the concentration of oil in the refrigerant is sufficiently low it may be carried through a horizontal or vertical suction line as a transparent colloidal dispersion.

4. Refrigerant-12 compressors can be designed which will put such a small quantity of oil in circulation that it would be exceedingly difficult to encounter an oil return problem except by tapping into the bottom of a horizontal suction main or by improper drainage at the evaporators.

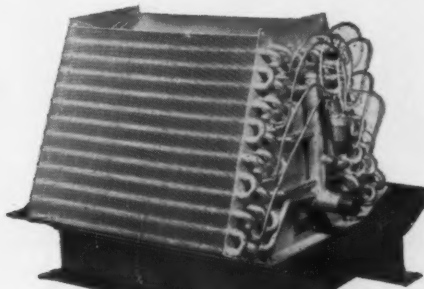
When aluminum is part of your product...



All aluminum home freezers



Cold-storage unit cooler



Air conditioning bonnet coil

check with ANACONDA ALUMINUM

Anaconda Aluminum combines the two features "most wanted" by aluminum buyers in selecting a source of supply.

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Second: You'll like the way Anaconda Aluminum's flexible operations will schedule your order fast, and ship it on time. This flexibility is designed into Anaconda Aluminum's new facilities for this one reason—*to give you the service you want!*

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ANACONDA ALUMINUM COMPANY • GENERAL OFFICES, LOUISVILLE, KENTUCKY

about these three great new compressors"

"For an example of what I mean, look at the air conditioner market for 4-5 room houses. Until now compressors have been either too large or too small. But with the new 30,000, 36,000 and 42,000 BTU rated units you can give this mass market just what it wants.

"Here are some reasons, over and beyond capacities, that help these new compressors surpass anything now on the market.

"One important reason is the surprising savings in space. And this smaller size is due to many factors. Better design is one. The high-speed motors are another because they allow use of smaller pistons with corresponding reductions in the sizes of the crankcases.

"The way vibration is reduced is really important too.

"Prices? I can assure you, as startling as it may seem, that these great new Bendix-Westinghouse compressors are priced lower than any other of similar capacity now on the market. In fact, prices are reduced as much as 25%.

"And they're really compact! Width, for example, is reduced 25%; weight 40%.

"We look upon these compressors as most significant engineering contributions to the industry.

"If you design, manufacture or sell air-conditioning units, you will want further information on how these new compressors, with capacities never before available in such compact size, open up whole new markets for your products."

Bendix-Westinghouse EVANSVILLE, INDIANA

A Division of Bendix-Westinghouse Automotive Air Brake Company, Elyria, Ohio • Export Sales: Bendix International, 205 E. 42nd St., New York 17 N. Y.

(*Continued from page* 77)

Nomographs – The nomograph, or alignment chart, is a useful method for presenting a complex of several variables and has naturally been applied to psychrometry. This type of chart is suitable only for presenting properties at a state point and not for graphical solution of an air treating or mixing problem.

Noteworthy among the nomographs are the Bureau of Standards charts published in 1935[20] showing properties of moist air over a wide range of temperature and pressure. Nomographs have also been prepared from time to time by individuals; an excellent example is a chart prepared by T. R. Simonson of San Francisco.

CONCLUSIONS

The general arrangement of principal coordinates now appears to be well established on charts in general use by the refrigerating and air conditioning industry, this arrangement being exemplified by both the ASHAE and ASRE charts. There appears little doubt that the basic coordinates should be moisture content and enthalpy (ASHAE chart) rather than moisture content and dry bulb temperature (ASRE chart). The enthalpy coordinate may be rotated to bring the dry bulb lines substantially vertical, thus the selection of enthalpy in preference to dry bulb as one of the basic coordinates does not change the general chart arrangement.

Use of enthalpy as one of the coordinates does not require that the enthalpy lines appear on the finished chart. The fact that the enthalpy and the wet bulb lines are so nearly parallel causes confusion if they are both shown. A practical solution is to omit the enthalpy lines in favor of enthalpy deviation contours and a scale of enthalpy at saturation.

Relative humidity is so well established in the refrigerating and air conditioning industry that its exclusion, at this time, would render any chart impractical. The use of both relative humidity and degree of saturation causes unnecessary complication. Since degree of saturation can easily be calculated by the division of two moisture contents, it appears desirable to omit this latter function from the chart.

The size of a psychrometric chart has considerable bearing on its practical usage. When too small it cannot be read with adequate accuracy, and when too large it becomes cumbersome to use and the necessity for multiple folding further detracts from its convenience. Many charts in use for the solution of refrigerating and air conditioning problems, printed letter size (8½ x 11), are readable to an accuracy that is consistent with the operating data for such systems.

REFERENCES

1. Psychrometry in the Frost Zone, D. D. Wile (Refrigerating Engineering, October 1944).
2. ASHAE Guide, 36th Edition (American Society of Heating and Air Conditioning Engineers, New York, N. Y., 1958).
3. ASRE Data Book, 19th Edition (American Society of Refrigerating Engineers, New York, N. Y., 1957-8).
4. Rational Psychrometric Formulae, W. H. Carrier (ASME Transactions, Vol. 33, 1911, p. 1005).
5. James Apjohn (Irish Academy Transactions, Vol. 17, 1837, p. 275).
6. Calculations for Dryer Design, W. M. Grosvenor (ALChE Transactions, Vol. 1, 1908, p. 184).
7. A review of Existing Psychrometric Data in Relation to Practical Engineering Problems, W. H. Carrier and C. O. Mackey (ASME Transactions, Vol. 59, 1937, p. 33).
8. A New Psychrometric Chart, E. P. Palmatier and D. D. Wile (Refrigerating Engineering, Vol. 54, July 1946).
9. ASHVE Guide, Vol. 23, 1945.
10. Proposed Psychrometric Chart, H. B. Nottage (Heating, Piping and Air Conditioning, Vol. 22, July 1950), (ASHVE Transactions, Vol. 56, 1950, p. 411).
11. The Mollier Psychrometric Chart, Ferdinand Keppler (Refrigerating Engineering, Vol. 27, 1934, p. 136).
12. Quoted from Side Lights on the History of Psychrometry, D. Dropkin (Mechanical Engineering, Vol. 63, May 1941, p. 369).
13. Ein Neves Diagram fur Dampfluftgemische, R. Mollier (Zeitschrift VD 1, Vol. 69, September 1923, p. 869).
14. Das ix Diagramm fur Dampfluftgemische (Zeitschrift VD I, Vol. 23, 1929, p. 1009).
15. The Psychrometric Chart, Its Application and Theory, W. Goodman (Heating, Piping and Air Conditioning, Vols. 11 and 12, June 1939 through August 1940).
16. A Mine Air Conditioning Chart, G. E. McElroy (Bureau of Mines Publication R.I. 4165, December 1947).
177. Heat and Vapor Transfer of Cooling Coils at High Elevations, N. Sharpe (Refrigerating Engineering, Vol. 6, p. 1055).
18. Psychrometric Charts for Use at Altitudes Above Sea Level, B. H. Jennings and A. Tortoni (Refrigerating Engineering, Vol. 62, June 1954, p. 71).
19. A New Psychrometric Chart, C. A. Bulkley (ASHVE Transactions, Vol. 32, 1926), (ASHVE Guide, Vol. 32, 1926).
20. Psychrometric Charts for High and Low Pressures, D. B. Brooks (National Bureau of Standards, Miscellaneous Publication M146, January 18, 1935).
21. A New Psychrometric Chart for Low and High Humidities, C. N. Deverall (Heating and

Ventilating, Vol. 38, June 1941, p. 51).
22. High Temperature Psychrometric Chart for Humid Air, J. R. Kayse (Air Conditioning, Heating, Ventilating, Vol 52, May 1955, p. 86)
23. Chart for Determining Air Volume, Relative Humidity and Temperature, B. A. Engelbach (Heating, Piping and Air Conditioning, Vol. 21, April 1949).
24. Psychrometric Charts for High Altitude Calculations, H. E. Kerig (Refrigerating Engineering, Vol. 52, November 1946, p. 433).
25. New Psychrometric Chart, M. Hirsch (Modern Refrigeration, Vol. 49, September 1946, p. 235).
26. Psychrometric Determination of Absolute Humidity at Elevated Pressures, W. M. Rohsenow (Refrigerating Engineering, Vol. 51, May 1946, p. 423).
27. A Method of Attacking Certain Fog Problems in Industrial Air Conditioning, A. Weisselberg (Heating and Ventilating, Vol. 28, Jan. 1931, p. 62, February 1931, p. 59).

BULLETINS

(Continued from page 97)

ylene, hydrogen and carbon dioxide, as well as the rare gases, are given in this survey of how each gas is made, delivered and used. One section of the booklet (ADC892) is devoted to the various systems for either gaseous or liquid delivery and storage. Covered are cylinders, bulk delivery and trailer bulk delivery units, and liquid station systems. There is also a conversion data table and a table on the physical properties of the various gases.
Air Reduction Company, Inc., 150 E. 42nd St., New York 17, N. Y.

Purifiers. Solution of many gas, air, steam and vapor entrainment problems is offered in Catalog 803, by picturing and describing the specification and operations of purifiers, separators, mist extractors and scrubbers. Thirteen Hi-eF purifiers are catalogued, including line types for entrainment removal service in large pipelines, receiver types designed for extremely large slugs of liquid, high pressure types capable of withstanding pressures up to 15,000 psi, exhaust heads for cleaning exhaust gases and vapors discharged to atmosphere, internal types for evaporator and boiler service and small line types for keeping moisture and dirt from damaging expensive pneumatic and steam tools.
V. D. Anderson Company, Div of International Basic Economy Corporation, 1935 W. 96th St., Cleveland 2, Ohio.

Steam Specialties. Composite product Bulletin 203, 12 pages, gives dimensions, capacities, patterns, weights and accessories of this line of valves, thermostatic traps, float and thermostatic traps, steam traps and pipe line strainers.
American Air Filter Company, Inc., 215 Central Ave., Louisville 8, Ky.

Multi-room Temperature Control. Stating axiomatically that the best way to maintain individual room temperatures under widely varying heating and cooling loads is to have the source of heating and cooling always available in each conditioned space, Catalogue EM59-2114 explains the Three Pipe Induction Unit System, utilizing this principle. Illustrations, diagrams and cost comparisons accompany the text.
York Corporaton, Div. of Borg-Warner Corporation, York, Pa.

Temperature Controls. Eight-page condensed Catalog CC covers temperature controls and allied equipment for industrial heating and refrigeration. The hermetically sealed Thermal Element, at the base of all this manufacturer's instruments, is explained. Indicating and non-indicating controls, process timers and limit controls for use in levels from –30 to 1100 F are described.
Partlow Corporation, 520 Campion Rd., New Hartford, N.Y.

Close-Coupled Pumps. Dimensions of small centrifugal pumps for air conditioning systems, small cooling tower systems and other package equipment are outlined, and design and material data are given in Catalog D-101.
C. H. Wheeler Manufacturing Company, Pump Div, 19th and Lehigh Ave., Philadelphia 32, Pa.

Standard Instrument and Control Panels. Details of construction, dimensions, weights, instrument mounting and accessories for six standard styles of instrument and control panels are in 16-page Product Specification G71-7.
Bailey Meter Company, 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Vibration Recorder. Bulletin K12A describes the Vibrograph, a small, non-electric, hand-held instrument which makes a tape recording of machine vibration amplitude. It enables taking of periodic readings of vibration amplitude to provide information which may be translated into terms of bearing or cutting tool wear.
Korfund Company, Inc., 48-15-53D 32nd Place, Long Island City 1, N.Y.

ASHRAE AT LAKE PLACID

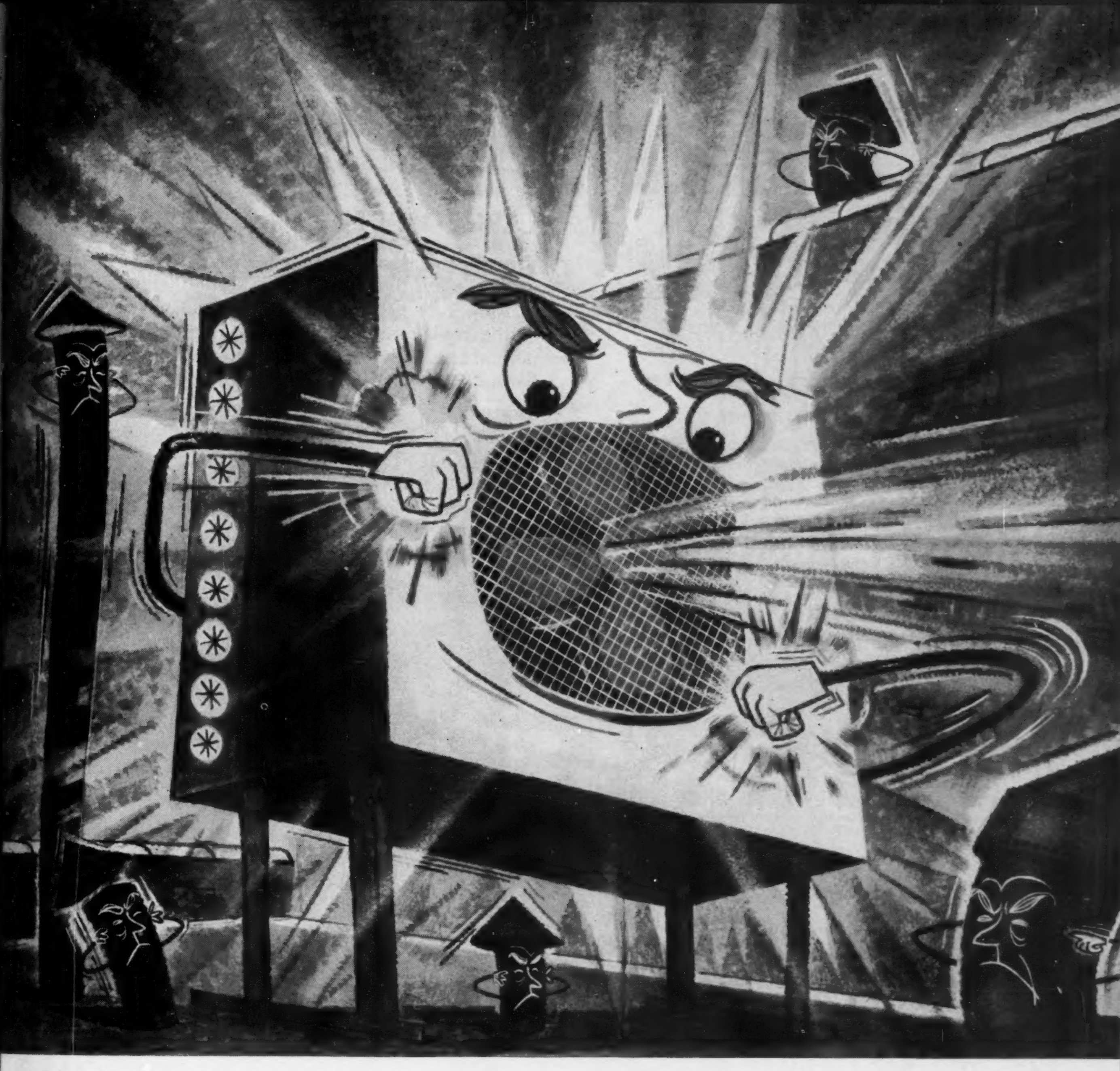
(*Continued from page* 59)

tails of the design of specific installations, were outlined by P. J. Marschall, Abbott Laboratories. Ventilation in the steel industry was the topic of F. E. Tucker, Weirton Steel Company, who gave a detailed description of a small steel company's heating and ventilating systems. W. G. Hazard, Owens-Illinois, pointed out methods of measuring radiated heat, how to evaluate it comfort wise, and how to control.

"The rapid increase in use of liquefied gases for industrial, defense and space probe purposes has necessitated a scientific and engineering approach to the production and handling of a variety of cryogenic fluids," V. J. Johnson, Cryogenics Engineering Laboratory, Presiding Chairman at the Cryogenics Conference, stated. The more popular aspects of handling cryogenic fluids of specific interest to ASHRAE members were discussed at the Conference – pumping, transferring, storing, flow measurement, liquid level detection, pressure drop, temperature measurement and the design features of pertinent equipment.

R. B. Jacobs of the Cryogenic Engineering Laboratory discussed present status of equipment and techniques for the transfer of cryogenic fluids through piping systems, and summarized several calculation procedures. Advantages and disadvantages of using cryogenic fuels and oxidizers, cited by L. J. Schafer, Jr., Pesco Products, Div of Borg Warner Corp., led to a discussion of mechanical and hydraulic design considerations for cryogenic pumps. C. Gettelman, Lewis Research Center, N.A.S.A., explained how the requirements of the instrumentation vary with several factors.

Highly informal, "off the record" discussions with no prepared papers, the Forums at this meeting proved to be of great interest to members. Six diversified subjects, selected on the basis of popular interest expressed from various sources, were covered as follows—Status of New Utilization Voltage Proposals for Air Conditioning Equipment, with A. S. Anderson, Ebasco Services, as Moderator; Icemaker Design Considerations, Moderator, E. MacLeod, Carrier Corporation; Research, the Engineer, and the Appliance Industry, E. A. Baillif, Whirlpool Corp., Moderator; Immersion Chilling of Poultry, moderating was E. N. Kerrigan, York Corporation; Sound and Vibration Problems in Air Delivery Equipment, J. B. Graham, Moderator, Buffalo Forge Co.; and Freeze Protection of Heating Coils, Earl Wilson, Moderator, Abbott Laboratories.



BEFORE YOU BUY, THINK:

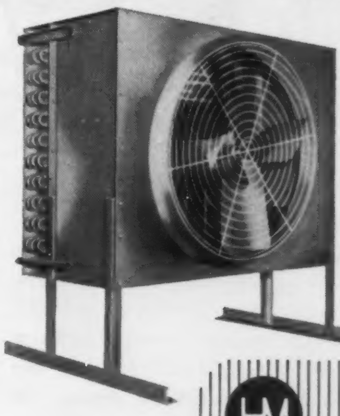
Will your air-cooled condensers sound like thunder?

Not even from close up if they're by Halstead & Mitchell

Fan noise, vibration and rattling have been engineered out of H&M air-cooled condensers. Deep pitch fans are run at slow speeds. Casings are rugged; won't loosen with use.

H&M condensers are completely dependable. The large coil and exclusive Turbu-Flo fins improve heat transfer by up to 15%. Fins are spaced widely to avoid clogging by dirt and other air-borne particles.

Winter operation is easy, too, with H&M's special modulating valve. Halstead & Mitchell air-cooled condensers are available in propeller fan or blower models. Multiple circuiting at no extra cost. Ask your local distributor for complete information, or write to Halstead & Mitchell, Bessemer Building, Pittsburgh 22, Pa.



H&M AIR-COOLED CONDENSER

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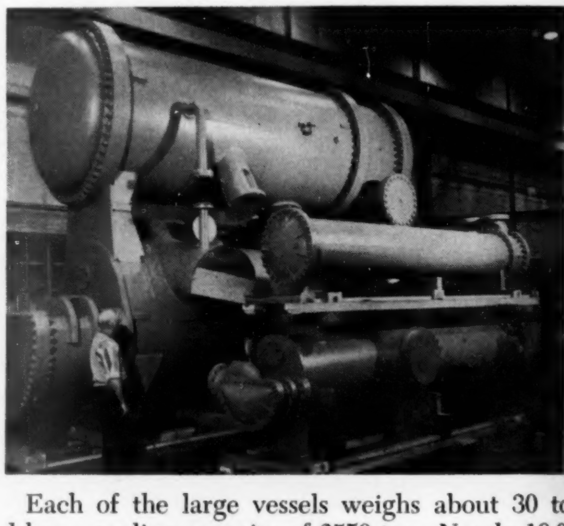
Water-Cooled Condensers · Cooling Towers · Air-Cooled Condensers · Finned Coil Products

Applications

LARGE WATER CHILLER

Two identical water chilling vessels will be used to air condition the 60-story Chase Manhattan Building in New York City. One of these units, as illustrated in the background, is 5½ times the capacity of the normal assembly for the Canadian Bank of Commerce, in the foreground.



Each of the large vessels weighs about 30 ton, and has a cooling capacity of 3550 ton. Nearly 18,000 gpm of water will pass through the cooler and condenser shells of each unit when operating. The coolers will work alongside a smaller chiller on the 11th and 31st floor of the new bank building. Total capacity of the four machines will equal 9140 ton.

AUTOMATIC ICE CREAM PROCESSING

Pumps covered with a thick layer of ice and frost circulate brine through the shell and tube brine cooler which supplies refrigeration to four Gram machines, automatic ice cream processing units, at the Good Humor Corporation's Brooklyn plant.

Four self-priming Deming Company centrifugal pumps operate 24 hours a day and have a total capacity of 1000 gpm. Outside the building there is a large turbine pump which supplies cooling water for the ammonia condensers, ice cream mix, and water for other cooler and compressor water jackets.

EXPANSION TOTALS 16,677 TON

Rockefeller Center's integrated air conditioning system will be expanded with the addition of a 1500-ton capacity centrifugal refrigeration machine. The Carrier Corporation unit will increase the Center's system capacity to 16,677 ton. When it is installed next to two centrifugals in a sub-basement, the water chillers will be part of a 7900-ton, eight-machine system that furnishes cooling for use in air conditioning large spaces in the 15-building project.

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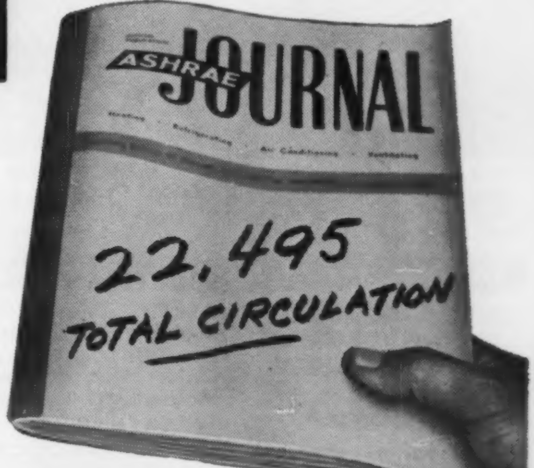

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AMERICAN SOCIETY OF HEATING REFRIGERATING AND AIR-CONDITIONING ENGINEERS
62 WORTH STREET, NEW YORK 13, NEW YORK

MULTIPLE ZONE AIR UNITS MEET STRICT REQUIREMENTS

Delivering a total of 76,000 cfm of cooled and filtered air to maintain a db temperature of 80 F at 50% rh, four Westinghouse Electric Corporation multizone air distributing units have been installed with two air conditioners in a spectograph laboratory and an IBM room of the Mallory-Sharon Titanium Corporation.

To keep the air in the spectograph laboratory, which has a cooling requirement of 97,000 Btu/hr, at constant temperature and moisture content of 72 F and 50% rh, one type of Unitaire conditioning units with electric reheat coils and hot water humidifier was installed. Another Unitaire system was installed in the IBM room, a space with strict air requirements of 73 F and 45% rh. The cooling load here is 200,000 Btu/hr.

The multizone units also comfort-condition the other areas of the two-story building in Niles, Ohio.

MISSILE DETECTION TRAILERS USE LOW VELOCITY AIR

Operators and sensitive electronic equipment in the close quarters of newly developed mobile radar vans designed to detect enemy missiles are cooled by use of a low velocity air diffusion panel.

As the van ceiling is only 3 in. above the head of the average operator, the diffusion space is limited to a narrow central "corridor." The air diffusers consist of panels with perforated distribution plates which, by means of a pressure displacement valve, slow down the speed of the cool air and diffuse it evenly throughout the air conditioned area.

One to two panels, each with six valves, are mounted in the ceiling of the Army electronic trailers. The air is brought to the panels from the cooling source through the plenum above the van ceiling.

Ground Systems Group, Hugh Aircraft Company, Fullerton, Calif., solved the mobile unit problem with Multi-Vent, panels of the Pyle-National Company.

AUTOMATIC REFRIGERATION IN FROZEN FOODS WAREHOUSE

Compressor equipment consisting of two York 9 x 9 VSA reciprocating units on high stage and two FES-Fuller rotary compressors on low or booster stage maintains a –8 F cold room temperature to within one deg of variation in Central Warehouse Corporation's new frozen foods warehouse in Albany, N.Y. Total capacity of the system is 100 ton of refrigeration with all four units in operation. For smaller loads, the units are set up to operate alternately, capacity being regulated automatically according to demand by means of controls sensing changes in pressure.

Long suction gas lines and low design temperatures common to the frozen food industry cause higher suction gas temperatures and lower pressure than in other refrigeration applications, tending to reduce the capacity of the system and increase the hp per ton of refrigeration required. Design of a rotary compressor suits it for operation at low suction pressures

where gas volume per lb of refrigerant handled is high. The high stage reciprocating compressor is especially adaptable for refrigeration gas pumping at high pressure differences across the machine. Combination of the two types of compressors gives the most efficient arrangement of compression equipment for this situation.

An automatic detection system signals the existence of four unfavorable conditions in the plant: low water to condensers, rising storage room temperatures, excessive ammonia pressure in condensers, and liquid ammonia at the compressors. Any one of these conditions will impulse the system and an engineer will be dispatched to the plant.

During the intermediate season between fall and winter, the evaporative condensers are arranged to operate dry when the outside air temperature is 40 F or below. An air sensing thermostat cycles the evaporative condenser water pumps. At the start of the winter season, the operating engineers drains the water from the evaporative condenser and it operates dry continuously.

VACUUM DEPOSITION CYCLES CUT BY MOISTURE-TRAPPING

In finishing by vacuum plating, removal of moisture has been found by Eastman Kodak Company substantially to reduce normal metallizing cycles. Results were obtained by incorporating a mechanically-refrigerated cold trap in one of the two 48-in. vacuum coaters used to metallize cellulose acetate-butyrate reflectors for all of Kodak's flash holders.

Presence of moisture in the atmosphere causes excessively long pump-down cycles, the difficulty arising from the extra pumping load imposed on the diffusion pumps by the water vapor. The traps circumvent this by producing temperatures low enough to condense the water vapor to ice before it reaches the diffusion pumps, during the fine pumping portion of the coating cycle.

The moisture-trap consists of a cooling coil built into the high vacuum system. A low-temperature compressor supplies refrigerant to the coil to maintain its surface temperature below −100 F. The coil is designed so that no heat is radiated to it from the tungsten filaments inside the chamber during firing, eliminating danger of pressure-burst created by vaporizing ice.

REFRIGERATING SYSTEM FOR TEST MODULE

Erected recently at the Bendix Aviation plant in South Bend, Ind., was a test module for experimenting with equipment used to handle aircraft fuels. Due to the constant recirculation of air and fuels, with resultant production of heat, refrigeration was required for chilling large quantities of water to temperatures between 45 and 55 F.

Arranged in groups of two, 12 Frick compressors were installed, each group having a capacity of 100 ton of refrigeration. Refrigerant-12 is used in a

straight compression system, under automatic control, the water chillers being of the shell-and-tube type. Each of the compressors has 6 cylinders.

In cold weather, the cooling tower, which provides condensing water for the refrigerating system, is able to carry the refrigerating load without the use of the compressors.

3000 TON COOLING GOES TO 15TH FLOOR

Lack of a basement in which to place the equipment necessary for a central air conditioning system by Con Edison Steam, first step in the modernization of the 34-story New York General Building at 230 Park Avenue, required the erection of a penthouse on the 15th floor setback to house two 1500 ton steam turbo-compressors, cooling tower and associated equipment.

Designed to deliver over one million cu ft of air per min, the system will effect a complete change of air every ten minutes. Cooling is provided by the 3000 ton steam turbo-compressor installation, which has an equivalent refrigerating capacity of 3000 ton of ice per day.

To efficiently air condition all areas of the building, a high velocity induction system serves the peripheral office areas, while interior areas are supplied through a low velocity system utilizing ceiling diffusers. Four zones are needed to gain maximum efficiency in the vast area of the interior floor space on the 2nd to 15th floors.